INDUSTRIAL RESEARCH

NOVEMBER-DECEMBER 1959

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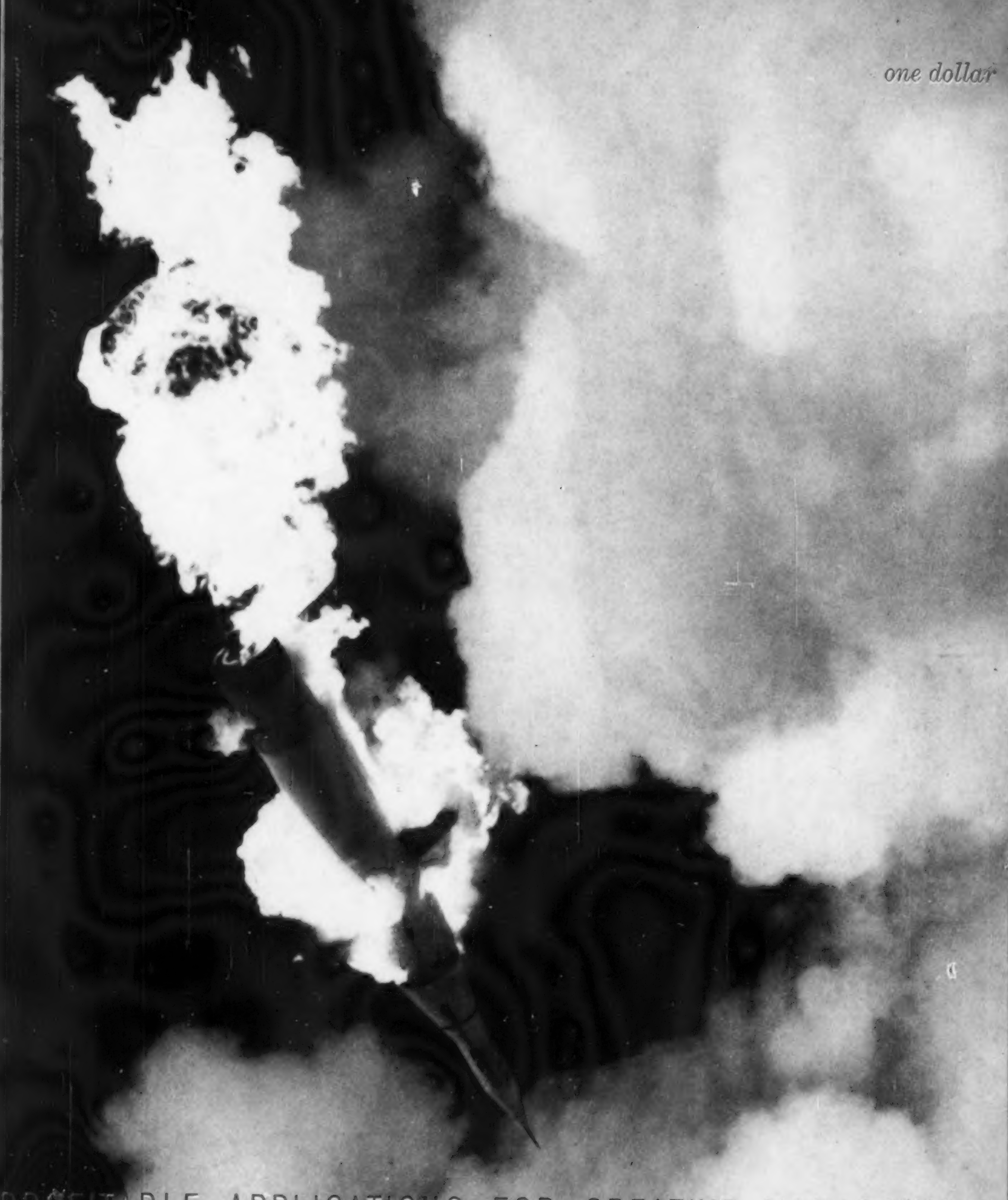

PROFITABLE APPLICATIONS FOR CREATIVE MANAGEMENT

INDUSTRIAL RESEARCH

EDITOR'S COVER NOTE: *The Juno II exploding over Cape Canaveral focuses attention on the most important single problem facing our space industry: reliability.*

The fact exists that U.S. missile failures are epidemic, that the Soviets have pinpointed a landing on the moon, that they could just as easily pinpoint an ICBM on New York or Los Angeles. Yet missile research is trial and error, and scientists learn something from every rocket that leaves the pad, no matter how inglorious its end.

In this case, the Army's Juno II veered dangerously inland as soon as it was launched. The range safety officer jabbed the destruction control. The huge rocket, built around the usually reliable Jupiter, crashed to earth some 150 ft. from the blockhouse. Reliability? At least the "destruct" mechanisms succeeded.

This issue carries a special section on space technology. Articles tell the Russian view on how satellites will be applied (page 44); truth and fiction regarding the near-future of space technology (page 53); how earthbound research is progressing via space simulation techniques (page 63); and the past and probable future "history" of the rocket (page 70).

The spectacular "failure" belching fire and smoke across I•R's cover, underlines the aspirations implied in these articles: if space is to be conquered—and if American scientists are to be the conquistadores — reliability first must be mastered.

Upcoming

Reliability—an Engineering Problem for Management

The Automation Controversy

Microminiature Components

Throw Away Your Clothes

The Flying Belt Is Here

Industry's Urge to Conform

STATE-OF-THE-ART ARTICLES

SPECIAL SECTION: SPACE TECHNOLOGY

DEPARTMENTS

Industrial Research magazine is published to help management men and engineers keep informed of the profitable applications of research in all fields of industry. Its goal is to help place research on a par with other management functions, such as sales, finance, production, and engineering, and—by doing this—to help reduce the time lag between invention and production.

INDUSTRIAL RESEARCH
200 S. MICHIGAN AVENUE • CHICAGO 4

the new bimonthly management magazine

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Editorial: Professional science writers, industrial executives, research workers, educators, artists, and photographers are invited to query the editor at address above, with ideas for articles or art. Do not send manuscripts without query. Answers to queries are prompt.

INDUSTRIAL RESEARCH

NOV-DEC 1959

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STATE-OF-THE-ART ARTICLES

SPECIAL SECTION: SPACE TECHNOLOGY

DEPARTMENTS

I R research on research

ONE OF THE MOST USEFUL "research on research" reports to emerge in recent months is A. D. Little's two-volume document, *Basic Research in the Navy.*

Since the Navy Department is the most basic research-minded of the three armed services, the report on its suggested direction becomes a commentary on the nation's military potential. In addition, the research sets forth a mathematical model for finding the optimum relationship between basic and applied research for a given program.

In every invention there exists a key fact, the last to be discovered of all the facts, relationships, and principles that were necessary before the invention can be made. The date of discovery of this key fact is the earliest date at which an invention can be made. Some inventions have been made very quickly after the discovery of the key fact, others have been made long after, but no invention ever was made before discovery of its key fact.

The body of basic knowledge that exists in the world contains a certain number of key facts, corresponding to an essentially equal number of possible inventions. If no new knowledge is added by research, these represent *all* the inventions that can be made.

Mathematical model

The A. D. Little researchers have attempted to symbolize this process by comparing it to a two-stage chemical reaction:

$$A \longrightarrow B \longrightarrow C$$

A represents the key facts not yet discovered. B represents the key facts which have been discovered but not yet applied. C represents the final applications. The first step is the research process of finding the key facts. The second step is the process of invention.

The chemical analogy suggests (and the theory of search developed during World War II reinforces) the idea that the rate of the first step is proportional to effort put into the process and to the number of undiscovered facts. Similary, the rate of the second step should be proportional to the effort put into it, and to the number of discovered, but unapplied, facts. Thus, the first rate should be of the form:

$$k_1E_1A$$

and the second form:

k_2E_2B

where E_1 and E_2 are the respective efforts, and k_1 and k_2 are the two constants of proportionality.

The constants k_1 and k_2 are measures of the relative ease with which the two processes can be carried out. If k_1 and k_2 are equal, the two processes are equally easy. If $k_1 = 10k_2$, it is 10 times as easy to find a fact as to apply it, and so on.

Discovery vs. application

From data the researchers were able to find, the mathematical model indicated a ratio of k_1/k_2 in the neighborhood of 2. *That is to say, it is twice as easy to discover a fact as to apply it.*

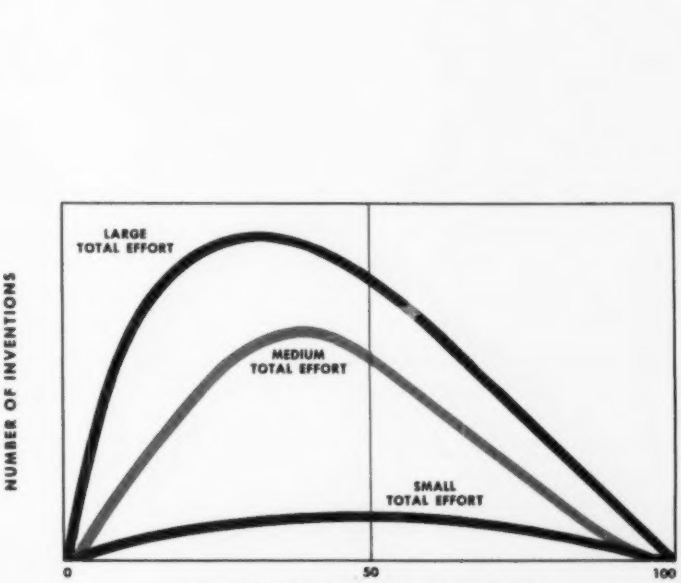
It cannot be assumed that this ratio is universal; it may vary from one field of research to another. Nevertheless, the data do suggest that the general lines of the theory may be correct.

If this theory of the research process can be accepted, it now becomes possible to study the problem of the correct distribution of effort between the two steps. It is clear that both kinds of effort are necessary; the question is: how should a given total effort be divided?

If too much effort is put into the first step, and too little into the second, the result will be the discovery of a large fraction of the key facts, but application of only a small fraction of those discovered. If too much effort is put into the second step, and too little into the first, only a small fraction of key facts will be found. While a large fraction of the discovered facts will be applied, the number of applications will be small because the number of discovered facts is small.

The situation is shown in the chart. The three curves represent three levels for the total amount of research effort put into development of a field. Each curve shows how the total result of the effort (measured as the number of inventions) changes as the distribution of the effort between basic research (step 1) and applied research and development (step 2) is varied.

If the total effort is small, the best result is obtained when the two efforts are equal. As the total effort is increased, the position of the maximum shifts. How this shift takes place depends on the "ease factors," k_1 and k_2 The curves shown are drawn for a case in which k_1



DEPENDENCE OF RESEARCH RESULTS ON DISTRIBUTION OF EFFORT

(continued on page 60)

I•R LETTERS TO THE EDITOR

Institutes vs business

Sir:
Dr. Clark A. Dunn *(Research Business vs. Research Institutes)* has ignored many basic principles of taxation and administration. Research institutes do not perform applied research at lower costs because of tax-exempt status, but they do have a much greater profit margin with which to install more expensive equipment and expand facilities on tax-free dollars.

This is a tremendous competitive advantage which is fundamentally unfair and eventually could eliminate tax-paying competition.

Applied research is a professional business service and must be considered in the same light as law, medicine, or any other professional service.

Dr. Dunn has presented a pleasant review of certain research activities but has developed nothing to justify the tax-exempt status of so-called nonprofit institutes.

Lewis E. Harris
President
Harris Laboratories Inc.

Sir:
The panel discussion between Dr. Roger Truesdail and Dr. C. A. Dunn is a valuable contribution to understanding in this field. I was particularly pleased to see the emphasis you give to the subject of fundamental research. This is a much more profitable field of enterprise than ordinarily is believed, both from the standpoint of the needs of our country and commercial profits.

Harold M. Dudley
Executive Secretary
American Council of Independent Laboratories Inc.

Sir:
I wish to say that you certainly have shed enough light on some of these interesting subjects. We enjoy *I•R* very much and pass it around among our departmental people, and they have all had noteworthy things to say about it.

R. O. Lane
Vice-President, R&D
Macklin Co.

Sir:
Dr. Clark A. Dunn's laissez-faire attitude with respect to industrial research at tax-free universities is most shocking. He apparently wants no "arbitrary regulations," "controls," or "short-sighted customs" like taxes and definitions to hamper the university research teams.

Tax-paying independent laboratories most certainly would agree with this position if the university were performing its traditional role in scholarly research. However, when the universities have diminished this role, and are serving private industry privately, and are competing unfairly with their own product—their graduated scientists and engineers — then the independent laboratory, in all fairness to its own professionals, must challenge the favored tax-free position.

Perhaps even more, we would appreciate it if they would stop sneering at the tax-payers.

H. E. Gaffney
Associate Director of Research
U.S. Testing Co. Inc.

Underwater

Sir:
Your article *Underwater Water Manipulators* was of much interest to me, particularly the part concerning the moving of air through "ductless ducting."

We developed a "ductless duct" system in 1943 which was used extensively in engine cooling of armoured vehicles, particularly the M4A1 tank. The system was generally known as the "ductless duct" and its success at the time indicated other possible uses such as you have suggested. This does not in any way detract from the work the Future Products people are doing as I think they are opening up a new field having tremendous possibilities.

W. W. Kennedy
Manager,
Air Distribution
Barber-Colman Co.

Sir:
I was very interested in the first copy I had seen of *Industrial Research*. I am particularly interested in the feature article entitled *Underwater Water Manipulators.*

C. W. Onan
D. W. Onan & Sons Inc.

Sir:
Truly, it would be heartwarming to you if, along with us, you could witness the stimulating effect and enthusiastic responses from those who have read the *Underwater Water Manipulators* article.

George E. Gross
President
Future Products Research Inc.

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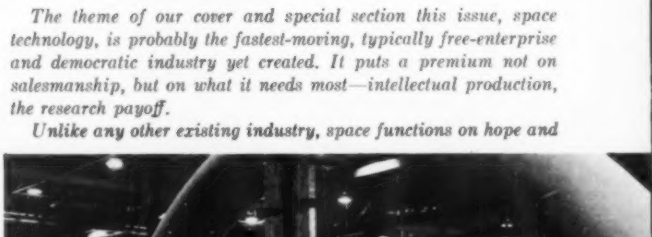
Notes about the fourth issue

I•R number four is a veritable transportation issue, primarily through space, but also on land, for the stay-at-homes. Insights into new ground transportation are provided by "Another Automobile Revolution," (hinting that they're frequent) and "Can Research Save the Railroads?" That question is answered only with difficulty in the "old" industries. The function of R&D in space is quite another matter.

Today communicators speak of the "space business" to listeners who don't bat an eye. Ten, even three, years ago eye-batting was reaction du jour.

The theme of our cover and special section this issue, space technology, is probably the fastest-moving, typically free-enterprise and democratic industry yet created. It puts a premium not on salesmanship, but on what it needs most—intellectual production, the research payoff.

Unlike any other existing industry, space functions on hope and future possibilities, conquest of real-estate unseen, of near-vacuum unexplored. At once it obliterates the economic reason for war, the threat of overpopulation, or cultural stagnation; offers to replace



Space is big business.

Land's color rediscovery

Sir:

Referring to Dr. Land's red and white full color in *Blue-Sky Profits*—color perception is explained as a neuro-physiological phenomenon, but I wonder if this does not point up the analogy between photo sensors and the human eye. The scotopic vision (3,700 to 7,900 A) overlaps the photopic vision (4,000 to 7,600 A) in monochrome blue-green only.

Could it not be that the pigment rodopsin on the rods (visual purple) and the iodopsin on the cones could be a similar filter effect to produce the sensation of full color without having to resort to some complicated brain action? And that a similar mechanism (photo sensor) exists in the retina? I remember stories of people seeing full-color images reflected from a television image by a red mirror.

W. Edwards
California, Md.

Electroluminescence

Sir:

In this Summer 1959 issue, there was an article entitled *Tomorrow's Light is Here*. We, at Sylvania, have pioneered not only in electroluminescent research, but in actually marketing panelescent devices.

O. H. Biggs
Vice-President,
Research & Engineering
Sylvania Lighting
Products Div.

Engineer shortage

Sir:

A few points concerning the so-called shortage of engineers (***Is There Really a Shortage of Engineers?***) should be clarified before people are convinced that such a shortage exists.

In the first place, Mr. Kubicek's general definition of a shortage seems to be based on the fact that interviewers were not swamped by applicants. The existence of a situation where there are good jobs for all qualified people does not in itself spell "shortage." It does serve to prevent exploitation and salary "situations." There was no unemployment of chemists during the depression, it has been said, but were they working as drug clerks or *as chemists?*

I have not yet seen any indication that any essential engineering activity ever was curtailed for shortage of personnel.

The figures cited in Mr. Kubicek's article showing the increase in salaries of engineering levels as indicative of shortage, when corrected for the overall increase in economic status of the American people, indicate only that chemists and engineers are as well off as they used to be.

Lastly, there are a great many advertisements seeking engineering help over the country, but I wonder if the real purpose behind these ads is not merely to portray a public relations picture.

R. B. Greene
Coordinator, Plastics & Resins
R&D, Allied Chemical

(continued on next page)

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guesswork with the scientific method for archeological, philosophical, and religious themes.

Any industry that promises so much and has arisen so quickly is easily misunderstood. A research director of Bell Labs attempts to separate sense from nonsense on p 53; Ari Shternfeld offers a Soviet-eye view of what satellites can be used for on p 44; two environmental test-facility manufacturers present a how-to-do-it-before-we-get-there program on p 63; and some Foote Mineral men round off the section with their interpretation of the past and future of our prime space machine: the rocket (p 70).

The dramatic rocket-bursting-in-air on the cover started out as a black-and-white Air Force photograph, was re-photographed at varying densities, dye-transferred, and air-brushed. Four-color plates were made and proofed in various combinations—blue for black, red for yellow, etc. The result: awful. (We used a duotone of the original.)

■

New in issue No. 4 is the column starting on page 37 by Lt. Gen. Arthur G. Trudeau, chief of Army R&D. The "Military R&D" column will attempt to point out both military and industrial applications of new government developments.

(continued on next page)

Opinions on 3rd Issue

Sir:

I am quite impressed with both the presentation and the type of material which your publication contains. It is a pleasant break from the usual and monotonous parade of advertisements for the equipment vendors and suppliers, and so far has contained several articles which are not only interesting to read but informative in fields akin to technical industrial efforts.

Frederick H. Roberts
Vice-president, Research
Union Carbide Plastics Co.

Sir:

As a subscriber to *Industrial Research*, I want to commend you on the splendid type, character, and quality of technical and professional articles which have thus far appeared in your periodical.

Karl R. Naumann
Commercial Research Consultant

Sir:

We hope you will continue to publish your *Industrial Research* magazine with the same care you have shown in your first issues. Its contents are very stimulating as demonstrated by the readers' letters to your office. The subjects covered are of great importance to industrial and research men and generally cover the fields in question very thoroughly.

Henri Marc
Vice-Chairman
American Pad & Textile Co.

Sir:

Your publication is certainly a fine effort and I am sure it will be most interesting and stir up interest.

Herbert Hoover
Former President

Sir:

Your publication fills a need in the field of R&D management, which has been badly neglected. Research on industrial research has been my hobby for the past 20 years.

George Perazich
Director of Research
Galaxy Inc.

Sir:

When I first heard of your *I•R*, I was frankly skeptical that it could offer anything that was not already covered by one or more of the existing publications.

The very first issue of *I•R* served to prove how wrong I was. I don't quite know how you do it or where you get your material but you do manage to get out a publication that offers entirely new slants on a wide variety of interesting subjects and research developments.

Edward S. Schultz
Research Consultant

Sir:

In our field, it is imperative that we be aware of scientific research and development. We have found *Industrial Research* an excellent source. Accurate and informative, the articles are also quite readable.

O. S. Granducci
President
Oeveste Granducci Inc.

Sir:

This is a most interesting magazine and I must say that every article in the Summer 1959 issue is intensely interesting to us and will give us a great background of fundamental information. In fact we are so interested in the articles that we would like to have two more copies.

Martin Sweets
President
The Martin Sweets Co.

I•R number four is both the last of the quarterly issues and the first of the bimonthlies. Industrial Research now will come to you every other month during 1960: January, March, May, July, September, and November. Subscription rates go up, but only proportionately. (*See page 104.*)

■

Credit line for the "Tomorrow's Spacecraft" illustration in the last issue got lost in the "gutter" of the magazine. The futuristic illustration was the work of Robert L. Thompson, art director at Consolidated Electrodynamics Corp., Pasadena, Calif.

■

All of the special sections printed so far in Industrial Research plus a new one on "Energy and Civilization" will be reprinted on heavy paper and published in hard-cover book form. The book, called Stimulus, will be available for Christmas gifts—ideal for the technical man or science student. Stimulus will cost $6.75 in bookstores, but can be ordered from the publisher for $4.95.

Sir:
I consider your last issue one of the most interesting magazines pertaining to our new electronics age. It's outstanding.
Joseph H. Jacobs
The Jacobs Wind Electric Co. Inc.

Sir:
I know magazines that are worse than yours. Yours, at least, comes close to the 8½ x 11 size. That's fine, keep it that way. Every week I am getting some weird sizes that fit no shelf, no briefcase, no envelope, nothing. Only use: wastebasket, unread.
Max F. Wulfinghoff
Professional Engineer

Sir:
The Summer issue has proved popular with my friends in the scientific community of Washington. In fact, so popular that my copy has disappeared.
Charles P. Beazley
Applied Science Laboratories Inc.

Sir:
Congratulations on bringing into fruition a publication which was badly needed in the field.
David L. Keith
Vice-President
H. M. Byllesby and Co. Inc.

Sir:
I have been very much impressed with the initial issues of ***Industrial Research*** and am glad to hear it will be published bimonthly beginning in November.
The freshness of this publication is, in my opinion, in the same category as ***Industrial Design*** magazine and should set new trends and standards in the publishing industry.
W. A. Romain
President
Sherman Products Inc.

Sir:
I•R is one of those rare publications in which the table of contents is for convenience only; all subjects being inter-related, it is read cover to cover. The format, art work, and illustrations are excellent.
Royal C. Gould
Meteorologist,
U.S. Navy

Sir:
Please accept my congratulations on the fine job you are doing with *Industrial Research* magazine. Both the content and format of your material are excellent.
Allan Lytel
Manager, Defense Marketing Publications
Avco Corp.

The world's hottest alloys

PART TWO, CONCLUSION

by **Harry B. Goodwin,** *metallurgy consultant, Battelle Memorial Institute*

ASIDE FROM ITS APPLICATION in electron tubes, molybdenum also is used as electrodes in the electrical resistance heating of molten glass, as wire for high-temperature furnace windings (in protective atmospheres or vacuum), for radiation shields (in sheet form) and other parts in high-temperature furnaces, and for piercer points for piercing steel billets.

It is being tried experimentally for gas-turbine buckets and nozzles, ramjet and rocket parts such as nozzles, leading edges, vanes and flame gutters, dies for die casting of brass, heat exchangers and pumps for liquid metals, ultra-high-speed aircraft skins, and many other uses. Molybdenum is available in sheet, rod, bar, wire, forgings, and extrusions, and it can be spun, welded, and machined by proper techniques.

Because of its grain-boundary weakness, arc-cast-molybdenum ingots tend to break up when attempts are made to forge or roll them in the conventional way. However, they can be extruded successfully into billets of circular cross section. The extrusion process modifies the grain structure sufficiently so that the billets subsequently can be rolled and forged like other metals. The grain structure of pressed and sintered molybdenum is such that this type can be rolled or forged without prior extrusion.

In working molybdenum, either by forging, rolling, or otherwise, the aim is usually to produce a "fibered" structure in which the metallic grains are elongated into needlelike shapes. (All solid metals are composed of myraids of tiny grains stuck together like the grains in a lump of sugar.) The metal is both stronger and less brittle in its fibered condition.

Molybdenum has been used primarily in unalloyed form. Only one alloy containing 0.5% titanium has reached commercial production. This alloy is not heat treatable.

The molybdenum-0.5% titanium alloy is stronger than unalloyed molybdenum. But even more important, for the same degree of cold work, its recrystallization temperature — temperature at which the fibered structure disappears when

the metal is heated — is several hundred degrees higher. (The recrystallization temperature is affected by the amount of prior cold work the metal has received.) Thus, the allowable service temperature for this alloy is that much higher.

In other words, the alloy can be used at a higher temperature without losing the stronger fibered structure. Molybdenum and the molybdenum-0.5% titanium alloy usually are placed in service with only a simple stress-relief anneal after working.

In addition to the development of the now commercial molybdenum-0.5% titanium alloy, experimental work has been done on alloying practically every element in the periodic table with molybdenum. Experimental alloys containing small amounts of zirconium and alloys of molybdenum and tungsten appear promising for some applications.

In addition, current research shows promise on the dispersion hardening of molybdenum by the addition of small amounts of metallic oxides to pressed and sintered molybdenum. The oxides of titanium (TiO_2) and zirconium (ZrO_2) have effected outstanding improvement in the 1800 F creep strength of molybdenum.

Moly can be welded

Molybdenum is readily resistance welded or arc welded, provided extreme care is taken to avoid contamination from the air, but the welds tend to have limited ductility. Best results have been obtained by welding in a vacuum chamber. Ordinary shielding methods are unsatisfactory and, even in sealed chambers filled with inert gases such as helium or argon, it is difficult to get gases pure enough to avoid contamination with oxygen and consequent embrittlement.

Because welding produces a cast structure, welds, although sound, are usually not very ductile (except in ultra-high-purity molybdenum) for the same reason arc-cast ingots are brittle, even when no contamination occurs during welding.

Molybdenum is one of the more difficult-to-machine metals but it can be machined successfully by all the usual machining processes if proper techniques are used and care is taken. Tools must be very rigid.

It will be recalled that molybdenum is the least oxidation resistant of the refractory metals. In air, it oxidizes at a rate 10 to 20 times that of the common steels. Considerable work has been done, without success, in an attempt to develop oxidation resistance in molybdenum by alloying. It now appears unlikely that an oxidation-resistant alloy can be developed which will have the desired mechanical properties, so some sort of protective coating is necessary.

A great deal of work has been done on developing coatings to protect molybdenum from high-temperature oxidation. Some of the types of coatings that have been tried are molybdenum disilicide coatings, single and multilayer electroplated metallic coatings, single and multilayer-sprayed metal coatings, chromized coatings, ceramic coatings, metal-reinforced ceramic coatings, and roll-clad coatings.

Molybdenum disilicide coatings are applied either by forming the silicide in place (siliconizing) or painting with a slurry of $MoSi_2$ and sintering. They give protection to rather high temperatures (2000 to 2500 hours at 2000 F and up to 300 hours at 3000 F). But, so far, they can only be used on lightly stressed parts not subject to mechanical shock or abrasion.

Roll cladding with nickel or nickel-base alloys appears to offer the most promise for a ductile coating, but unfortunately the top temperature limit for such coatings is fairly low, not much over 2000 F. Sprayed metal coatings of two general types — one based on aluminum-chromium-silicon combinations and one based on nickel-boron combinations — have shown some promise, but have only fair mechanical-shock and abrasion resistance

As yet, no completely satisfactory coating has been announced and there probably will be no one all-purpose coating. The use of molybdenum in many applications is being held up for lack of a satisfactory coating.

Ductile tantalum

Tantalum is the third highest melting metal and is one of the denser metals, being slightly less dense than tungsten. It is the most ductile of the refractory metals, with the best resistance to acid corrosion of any metal. Thus, it has been used chiefly in the chemical-equipment field. It also has application in electron tubes and, surgically, in the human body.

Tantalum occurs primarily as a complex oxide with columbium, iron, and manganese. It practically always is found together with columbium. The oxide concentrates are processed to potassium fluotantalate (K_2TaF_7), and the metal is obtained from this compound either by fused-salt electrolysis or

Columbium may well be the most plentiful of its group in the earth's crust, but it is not yet as available as tungsten or molybdenum.

sodium reduction. The metal is consolidated into bars by pressing followed by vacuum sintering.

Tantalum is used in unalloyed form. However, some alloys are being developed that will have greater high-temperature oxidation resistance than unalloyed tantalum. Possibly some combination of alloying and coating will be the ultimate solution to the oxidation problem.

Tantalum is worked cold. To facilitate further working it usually is annealed in vacuum after a 70 to 80% reduction in area, although it is possible to work it considerably more than this without cracking the metal. It is readily machinable and can be welded by resistance welding, with special precautions to prevent oxidation, or by inert-gas shielded-arc welding.

Development of tantalum-base high-temperature alloys has been held back because of tantalum's scarcity and high price.

Columbium is not scarce

Columbium — which only a few years ago was thought to be more scarce than tungsten, tantalum, and molybdenum — now is believed to be the most plentiful of the four in the earth's crust, although it as yet is not nearly so available as tungsten or molybdenum.

It has a considerably lower melting point than the other four metals mentioned, but its melting point is still some 1500 F above that of iron. It is the least dense of the four metals, having a density only slightly higher than that of steel. It is quite ductile, though not so ductile as tantalum.

In the past, columbium has been used as a minor alloying constituent, primarily in stainless steels, for carbon stabilization, and in high-temperature alloys. Although very corrosion-resistant, columbium has not found much use on this basis because tantalum is even better for most applications.

Currently, there is a great deal of interest in columbium for high temperature nuclear reactor operation. An airborne reactor, for example, has to operate at a high temperature if it is not to be too large and too heavy.

Columbium has low density, excellent strength at high temperatures, and a low "thermal neutron capture cross section" compared to other refractory metals. This "cross section" is a measure of the metal's tendency to "soak up" neutrons when placed in a nuclear reactor, thus tending to stop the nuclear reaction.

Columbium practically always occurs in nature with tantalum. It is separated by chemical treatment as columbium oxide, which is reduced to metal with carbon in vacuum. The powder is consolidated into solid metal by pressing and vacuum sintering in exactly the same way as is tantalum.

Although there have been almost no uses for the pure metal, enough experimental research has been done to learn a good deal about it. Columbium, like tantalum, always is worked cold. Fabrication, machining, and welding characteristics are similar to those of tantalum, and procedures are similar.

Research has shown that considerable improvement in the oxidation resistance of columbium can be effected by alloying.

Unfortunately the alloying additions which promote oxidation resistance in columbium tend to decrease ductility and fabricability. The problem is to achieve oxidation resistance without sacrificing these mechanical properties too much. Binary additions of zirconium, titanium, molybdenum, vanadium, chromium, tungsten, and possibly hafnium can improve the oxidation resistance significantly but not enough for most intended applications.

Additional alloying has produced further improvements in oxidation resistance. Alloys containing zirconium-titanium, titanium-aluminum, chromium-cobalt, iron-aluminum, and chromium-aluminum have shown up to a 2,000-fold improvement over unalloyed columbium in oxidation resistance at 1000 C.

The best of these alloys oxidize at rates slower than that of Nichrome (80% nickel and 20% chromium), which is considered to have adequate oxidation resistance in the temperature range of interest. Unfortunately, the most oxidation-resistant compositions have not been fabricable. Ohio State University recently announced development, under ONR sponsorship, of a columbium — 45 zirconium — 5 titanium alloy which is said to be both oxidation resistant and fabricable.

A combination of alloying and coating may be the best solution to the oxidation problem, with alloying serving to prevent defects in the coating from becoming cata-

ZONE MELTER *purifies refractory, reactive metals. Electron bombardment heats the metal (right), and a molten zone pushes impurities ahead as it passes along the specimen.*

strophic failures. In other words, because of the alloy content, a part will not fail very quickly after a coating defect opens up.

In general, it appears that solving the oxidation problem will be much easier with columbium and tantalum than with tungsten and molybdenum.

Spark-resistant rhenium

Rhenium has the second highest melting point of any metal and is one of the more dense metals. With maximum effort, an estimated five to 10 tons of rhenium could be produced annually from known sources. It is concentrated particularly as a byproduct of molybdenite obtained from certain copper ores.

The metal has three properties which make it of interest for special uses. First is its excellent resistance to electric sparking and arcing. It is superior to tungsten in this respect, and thus is of interest for electrical contacts in applications where longer life warrants a high price.

Another property of rhenium is its superior resistance to the "water cycle" attack which plagues the use of tungsten as a filament in electronic tubes. This is the transfer of metal from the filament to the cool walls of the tube through a complex reaction involving traces of water vapor left in the evacuated tube. The same thing is seen in the gradual blackening of tungsten-filament light bulbs.

The third unusual property of rhenium is its ability to overcome the grain-boundary weakness of molybdenum and tungsten when alloyed with these metals. An alloy of about 50% (by weight) rhenium with molybdenum is phenomenally ductile. Unfortunately, the limited supply of rhenium does not now permit considering this alloy for larger-scale use.

Rhenium also may find use in rhenium-molybdenum and tungsten-rhenium/tungsten alloy thermocouples. The former are said to be good up to 3200 F while the latter may be good to 4000 F. Neither combination can be used in oxidizing atmospheres without protection.

Unalloyed rhenium is worked cold with frequent anneals being required, since it work-hardens more rapidly than almost any other

metal. Strength levels of over 500,000 psi can be obtained by cold working.

Chromium: usually brittle

Chromium is well down the list of the metals arranged in order of the melting points. But it is the highest melting metal that's both reasonably plentiful and has really good oxidation resistance. Unfortunately, chromium metal is ordinarily completely brittle at room temperature (unless extremely pure), and completely impossible to work without cracking up at any temperature. It is this characteristic that so far has prevented use of metallic chromium and chromium-base alloys.

Chromium of commercial purity is made electrolytically from aqueous solution and by an aluminothermic reduction process. "Ductile" chromium is made from extra-high-purity electrolytic chromium prepared by a special process. This is repurified either by the iodide process (thermal decomposition of chromous iodide prepared by iodination of electrolytic chromium) or by high-temperature treatment with high-purity hydrogen.

The resulting product is arc cast under conditions carefully controlled to avoid contamination. Work also has been done on preparation of high-purity chromium-base alloys by powder-metallurgy methods.

Experimental chromium-base alloys fabricated into test bars by careful "babying" have exhibited high-temperature strengths superior to those of the present nickel and cobalt-base superalloys. The hope is that they may be useful at temperatures a few hundred degrees over the temperature ceiling for present nickel and cobalt-base alloys — which would be perhaps up to 2000 F.

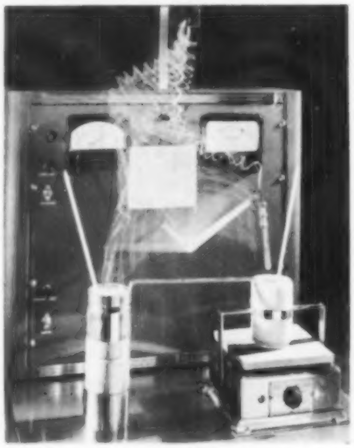
Possible applications for chromium-base alloys are in turbine blades for jet engines and in nuclear reactors. Chromium-base alloys almost certainly will be oxidation resistant, and no protective coatings will be required. However, it is expected that their practical temperature limit will be far below the limits for the other metals discussed here.

As a consequence of chromium's brittleness, it is now used only for plating and as a constituent in alloys based on other metals. Most of the research on chromium and its alloys has been directed along one of two lines:

- Discovering the cause of and overcoming the poor ductility of chromium itself.
- Achieving acceptable ductility while still retaining high strength at elevated temperature through alloying.

Evidence now available indicates that chromium itself, if pure enough, is inherently ductile. However, it is so exceedingly sensitive to embrittlement by very minute traces of impurities that some metallurgists doubt whether ductile chromium-base alloys are practical. Nitrogen, carbon, sulfur, nickel, and aluminum seem to embrittle chromium markedly. Surprisingly enough, oxygen — which is so damaging to the ductility of molybdenum — does not appear to affect the ductility of chromium very much.

MAGNESIA CRUCIBLES *(above) withstand long-term temperatures to 4350 F. A tantalum capacitor testing device (below) is used at Union Carbide in high-temperature research.*



The alloying approach has been unsuccessful in producing ductile chromium-base alloys when commercial-purity chromium is used as the base metal. But there is hope that better alloys can be made with ultra-high-purity chromium and with the other constituents also of high purity so as to keep out embrittling elements.

Australian researchers have prepared alloys of high-purity chromium with small amounts of tungsten (1 and 5%) and titanium (1%) which could be worked and which were ductile in strip form after electropolishing. Chromium-base alloys have not yet found service applications, but trials are underway for a number of possible uses. Brittleness and difficulty of fabrication remain the biggest stumbling blocks.

The platinum group — possibilities as coatings

The platinum-group metals have been used for years in laboratory apparatus, in the "bushings" (plates with tiny orifices through which molten glass flows to form glass fibers) of the glass-fiber industry, electrical contacts, catalysts, thermocouples, dentistry, jewelry, pen nibs, phonograph needles, and a few other special uses. A little over 60% of the combined consumption of all these metals is of platinum itself. About 30% is palladium.

Their high melting points and excellent oxidation resistance naturally suggest these metals for high-temperature alloys. Because of their scarcity, however, these metals can be used only for very special aplications. Their potential for high-temperature alloys is being explored at Battelle.

One possible application suggested for platinum and rhodium especially is as a coating to protect molybdenum from oxidation. Platinum cladding is very effective, but so expensive that attempts have been made to use platinum plating instead, which is not so effective. Rhodium appears to be the most oxidation resistant of the platinum-

New Foote Lithium Metal Dispersion . . . so reactive that it bursts into flame on contact with cold water. Light for the photo was supplied by the reaction.

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group metals and also has excellent high-temperature strength. A hazard encountered in working with osmium is that its oxide is extremely toxic.

What happened to cermets?

A great deal of research has gone into attempts to develop some ductility or at least toughness in nonmetallic materials, but with only limited success. The word "ceramics," as used here, covers not only oxides but carbides, nitrides, borides, intermetallic compounds, etc., as well.

Two general approaches have been taken: combining metals and ceramics, and attempting to develop ductility in pure ceramic materials.

The thought behind metal-ceramic combinations is to combine the ductility of metal and the oxidation resistance and refractoriness of ceramics. Much hope once was held for the so-called cermets, which may be thought of as ceramic particles held together with a thin layer of metallic "cement."

Six or eight years ago, cermets were seen as the best hope for a 2000 F turbine blade, for example. But in spite of a tremendous amount of research, neither ductility nor toughness have been introduced into cermets.

The best so far developed have impact strengths on the order of one-tenth that of present turbine-blade alloys. However, they do have excellent thermal-shock and oxidation resistance.

The chrome-alumina and nickel or cobalt-bonded titanium carbide type of cermets seem best because of the excellent bond developed between the metal and ceramic in these systems. Such a bond appears essential for a good cermet. Their fracture strengths are of the same order as those of the better all-ceramic materials.

While research has produced, as a byproduct, specialized materials for wear resistance, high modulus of elasticity, hardness, or improved thermal and electrical conductivity, it is significant that none of today's cermets have any structural application.

An interesting process for making metal-ceramic composites has been announced by Denver Research Institute. To obtain a dispersal of fine ceramic particles in copper, for example, boron is dissolved in one ladle of molten copper and thorium in a second ladle of copper. When the two molten solutions are mixed, a fine insoluble precipitate of thorium boride is formed, and the metal is frozen quickly before this can settle out. The same principle can be applied to other metal-ceramic systems. Tremendously increased high-temperature strength is claimed.

While composite materials so far have proven disappointing, there has been encouragement in work done on composite structures. A composite structure, in the sense used here, may take such forms as ceramic (or cermet) bodies with wire-mesh reinforcing imbedded in them, ceramic-coated metals, metal-ceramic laminates, and bodies made of metal wires or fibers stiffened and protected from oxidation by ceramic materials.

One promising application is the protection of metal ram-jet tail pipes by a metal-mesh-reinforced ceramic coating with the metal mesh welded to the tail pipe at intervals.

In a composite structure, one places the ductile component where ductility is required and the brittle component where it is not required. The metal may be placed in those parts of the structure under tension and the ceramic in those parts that are lightly stressed or subject to compressive stresses. The principle used in prestressed concrete also may be applied to these combinations.

Studies of possible ductility of pure ceramics have demonstrated some ductility in single crystals of certain high-purity oxides and other compounds.

There is considerable optimism among some ceramics people that true ceramics with greatly improved toughness and perhaps even a little ductility can be developed eventually. In the last few years, some great advances in ceramics have been made simply by improving the starting powders.

For some time to come, however, where toughness is a requirement, the metals discussed in this article will remain the world's hottest materials. ■

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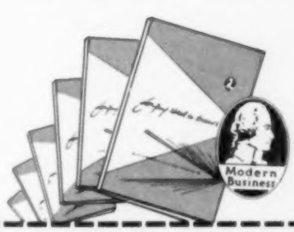

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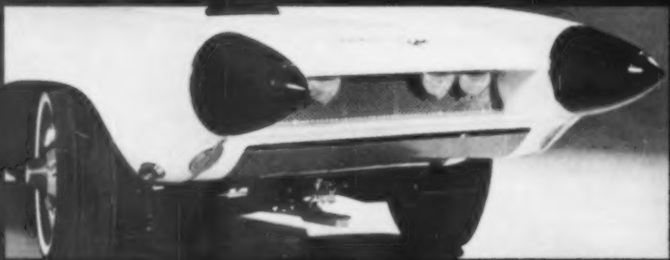

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THE LATEST HORSELESS CARRIAGES *employ compressed air and other radical propulsion and control methods, such as:* (1) *Princeton's* Air Scooter, *lifted and driven by an airstream;* (2) *General Motors'* Unicontrol, *that eliminates conventional steering wheel, brake pedal, and accelerator;* (3) *the Cadillac* Cyclone, *which incorporates radar locators into its rubber-tipped double nose, and retractable headlights into its grill;* (4) *the Curtiss* Air-Car, *that uses helicopter rotors for lift and can hover above rough terrain or over open water; and* (5) *an Illinois Tech student-designed* Skeeter Scooter, *mobilizing pedestrians; via roller-skate wheels and* (6) *simple, one cylinder model-airplane engine.*

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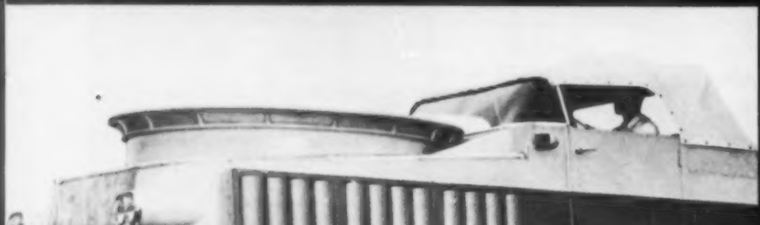

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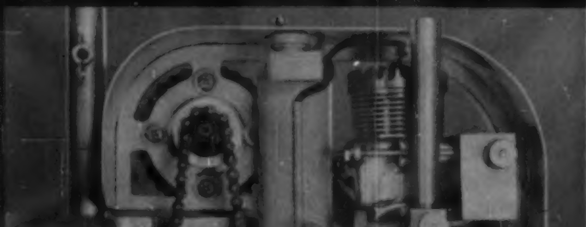


Another Automobile Revolution

by K. M. Wylie Jr.
I•R Contributing Editor

"NO ELEMENT *has gravity or levity within its own element. "Every heavy body desires to lose its heaviness."*

With these words Leonardo da Vinci expressed something of his intense desire to fly, to lift, to free himself from the surface of the earth by whatever force was necessary. In preparation for flight he studied winds, birds, bats, and theorized about the interrelation of forces, energies, weight, and gravity, speaking of a spiritual force.

When da Vinci tried to build a workable flying machine he failed, so the theory of scientific heritage goes, because the technical resources of his 15th and 16th century world still were too paltry to sustain his complex work. When he tried the wheeled vehicle, as in his scythed car and armoured car, he had more luck. Now, four centuries later, our scientific heritage plainly does enable us to put vehicles into the air. And we may be about ready to get rid of the wheel.

Not that engineers are ready to roll the wheel into oblivion immediately. But intensive work on hovering, skimming, and levitation vehicles by such organizations as Piasecki Aircraft Corp., Ford Motor Co., Chrysler Corp., Saunders-Roe Ltd., and Curtiss-Wright Co. indicates a trend away from tying down land-vehicles exclusively to this basic invention and chronological cousin of the bow & arrow and fire-stick.

Revolution No. 3—or 4

The significance of the air cars actually is that they are symptomatic of a whole range of research advances in what has been called variously the third or fourth automotive revolution *(preceded by other revolutions led by the* Model T; *the establishing of nation-wide marketing techniques for cars; and General Motors' institution of the annual model change, planned obsolescence).*

The new revolution consists of complete structural and design changes, not merely face-lifts, re-sculpted bodies, or bored-out engines. We have the metals, instrumentation, the plastics, and perhaps even the propelling force to build new kinds of automobiles. These vehicles will be completely new from the ground up.

Ride should be smoother, more stable for multiple reasons. Tires are being developed to run more quietly, stop faster, and keep rolling even with fist-sized chunks torn out of them.

While reports vary on the durability of new tires made with treads of softer (than standard tread rubber) butyl, it is true that they do not squeal as much as regular tires on turns and fast stops. Butyl absorbs considerably more energy when flexing than natural or other synthetic rubber. Both U.S. Rubber and Firestone Tire & Rubber Co. (compound X-99) are producing them, and Firestone has claimed 15% less wear for one of its tires; another claim by a butyl tire maker says durability is 11% better. Treads made of styrene butadiene are said to increase tread life on new Chevrolet tires 10 to 20%. Yet an additional report states that factory testers at one plant producing these tires recorded wear at three to four times standard-tire rate. Price probably will be about 20% higher than for standard tires.

In another tire development, Dayton Rubber Co. and American Latex Co. are testing a tire filled not with air but with controlled-density urethane. The big advantage of these tires is that they keep rolling normally even if torn by gaping holes. At this stage of the research program, riding quality seems

Automotive research in levitation soon may enable us to roll the

good, according to the developers, and cornering at speed, they believe, should involve low lateral distortion and good stability. Firestone now is testing tires made with Dacron polyester fiber.

Not only are higher, more nearly chair-height, seats apparently coming back, but more comfortable seating materials are under development. One seat construction method consists of molding coil springs directly into polyurethane foam instead of spreading a layer of some kind of spongy material over the springs after they're mounted.

For suspension, both coil springs and swing rear axles are going to be appearing on more cars in the near future. Cars with engines and/or transmissions aft commonly will have an A-frame, swing-axle suspension configuration. As for the new coils, they will be variable-rate coil springs, giving designers almost any variable-rate, load-deflection curve they need. Such suspension possibly would replace present types of both air-bags and leaf springs.

An interesting development in brake research reported by Chrysler Corp. is a new power brake actuated by compressed air instead of manifold vacuum. Big advantage of this design is supposed to be a smoothly advancing brake force curve, not developed by vacuum models.

The greaseless car

In recent years automobile grease fittings have been reduced from an average of 25 to 30 for each car to 10, but the no-greasing target remains. Extensive testing by American auto manufacturers is underway on bearings lined with Teflon TFE-fluorocarbon fabric.

Already, tests on a fleet of Baltimore taxis indicate a total savings of about $40 to $50 on greasing during the life of a family car (figured at $1.75 per lube job). In Germany, Daimler-Benz AG now is building cars with non-lubricated chassis and steering-linkage joints, and the new *Triumph Herald*, built in Britain, is the first production auto that completely cuts out chassis lubrication.

Power systems for the coming cars range over a broad spectrum of efficiency, complexity, and probable nearness to actual production. In a sense, the most complex engines are the ones nearest to us now.

One of the most immediate developments is the 170-cubic-inch, overhead-valve six cylinder engine developed by Chrysler for its *Plymouth, Dodge, Dart*, and new smaller-sized *Valiant*. So that it will fit under the low hood, the engine is canted 30 degrees to the right; the transmission in manual models is tilted 30 degrees to the left. This also results in a lower drive shaft hump. The block is cast iron; intake manifolds, pump cases, and distributor housing are partly aluminum.

Lying down still further is the new Chevrolet *Corvair* engine, a six-cylinder, aluminum pancake model with cast-iron cylinder sleeves. It is cooled thermostatically (only when rising engine heat triggers it) by a horizontal blower and ducting system which blasts air over the finned cylinder barrels.

Willys Motor Co. also is introducing a flat engine for 1960, but this all-aluminum model will be strictly for military use. It will have four cylinders, displace 164 cu. in., and develop 100 horsepower.

While current applications of such domestic opposed-cylinder models are new to the U.S., the engine as a genre is not. American busses have used pancakes for quite a few years. Willys already has another opposed engine, a 17-horsepower four, on the road, or more properly, the field, since it is the air-cooled aluminum model which pushes the armed forces' *Mechanical Mule*. Following World War II, Nash Motors built both four- and six-cylinder experimental flat engines.

Mass cast aluminum

One development which may spur the larger-scale production of aluminum engines is a new method, patented by National Lead Co., for mass-producing die-cast aluminum V-8 blocks at less than present-day costs for sand-casting iron. By comparison, a standard-sized V-8 aluminum block weighs 55 lbs., an iron block, 200 lbs. One main question raised about this die-casting method is whether it actually does produce engines more cheaply. Some automotive researchers believe that for design changes both costs and production time would be higher than with permanent molding methods.

New versions of existing internal combustion engine types continue both to prove themselves in operation and to move from the test stand to chassis.

About two years ago Perkins diesel engines were installed in *Plymouth* cars in Europe for sale there. Now

GM ROADSIDE TRANSMITTER ***automatically broadcasts vocal messages to standard radio receivers in passing cars. Information and directions are taped magnetically, give motorists warnings their eyes might miss.***

wheel into oblivion.

taxi operators are using them throughout this country, apparently with good results.

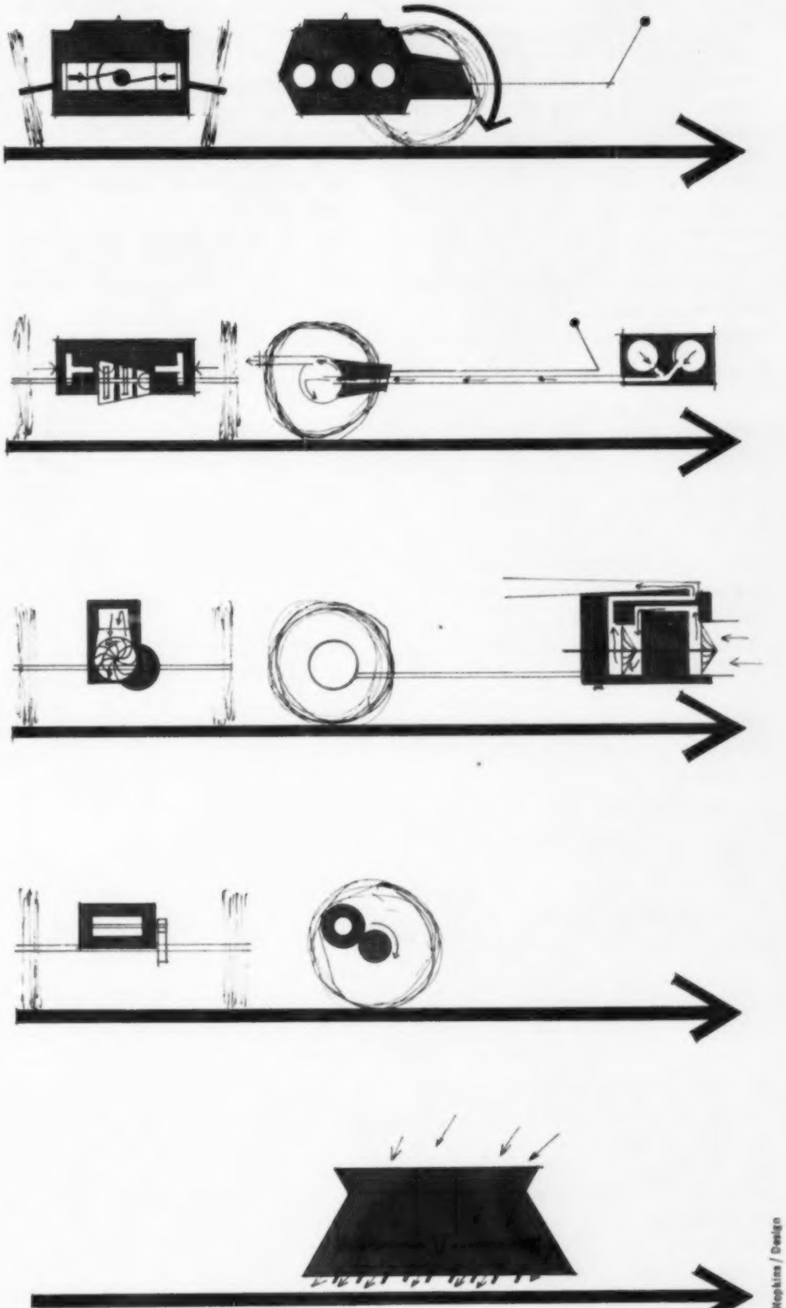
For a number of years, V-6 engines have been proposed for use as automobile power and some are running in Europe. Now General Motors has built such an engine for trucks. Main advantages are simplicity — it has fewer parts than a comparable V-8 — and compactness — it is shorter than a V-8 counterpart and has a cylinder-bank angle of 60 degrees, not 90. Then to give truck designers and users extreme flexibility in mating this new engine to various chassis types and sizes, this basic V-6 has been planned to include pistons, connecting rods, rocker-arm covers, intake manifolds, and engine heads which are interchangeable with GM's new 702-cubic-inch V-12 engine.

Simple turbines

When (or if) gas turbines are mass-produced and mounted to power motor cars it will doubtless be at that moment in their development when their simplicity outweighs their other disadvantages. On the good side, they don't need coolant or antifreeze; contain about 20% as many total parts as a piston engine (no cooling system and almost no ignition system, for example); have only three moving parts (one compressor, two turbine wheels) rather than multiple synchronized pistons, valves, timing parts; they can run on almost any liquid fuel; and they weigh only about half as much as piston engines of comparable horsepower.

The main turbine disadvantages have been inefficient use of their fuel's total heat energy; poor fuel economy; rather poor accelerator-control response; and high purchase price. All of these problems have been attacked by automotive turbine developers, including Chrysler, GM, and Ford.

Both Chrysler and GM have designed turbine components called heat regenerators which remove heat from the exhaust train (where it is undesirable because potentially injurious to pedestrians and other vehicles) and channel it back to the compressor area where it increases engine efficiency by pre-heating incoming air.



POWER UNITS *for new generation of automotive vehicles expend driving force with varying complexity, ranging from traditional engine-and-wheel combinations to the air auto's spinning fan. Models top to bottom include: rear-mounted, pancake reciprocating six (multiple pistons/transmission/differential/axles/wheels); free-piston (two pistons/gas conduit/turbine rotors/transmission/axles/wheels); gas turbine (turbine rotors/transmission/differential/axles/wheels); electric (armatures/reduction gears/axles/wheels); and air car (piston engine or turbine/gearing, if needed/fan).*

Working to better fuel economy and accelerator control, Chrysler engineers have made several recent advances. In 1957, a turbine-powered Plymouth, the *Turbine Special*, driven from Detroit to Woodbridge, N.J., averaged 13 to 14 miles a gallon. For a run made this year over the same course, the average had been raised to 19.39 mpg. In the same vein, time lag from throttle increase to full torque output of Chrysler's turbine has been cut from six seconds to about one second.

Turbine prices will not drop until turbines are mass-produced on a passenger-car sale, and such assembly-line output will not start rolling until various bugs, kinks, and sticklers have been shaken out of them. To help in this shaking and, at the same time, make use of their advantages, though, they can and will be used in heavier vehicles.

For example, General Electric has announced the Marine Corps is going to get a new 29-foot combination amphibious troop carrier and tank which will be powered by a turbo-shaft engine. GM is to turn out a limited number of the same *GT-305 turbines* used as powerplant in its futuristic *Firebird III* research auto. These will be used as powerplants in buses, trucks, and military vehicles for in-service operating information.

Boeing's truck

Yet, gas turbine research has not been limited to the GM turbines, Ford's *704* unit, or the Chrysler turbines, nor has it been confined to this country. Starting in 1950-51, Boeing Airplane Co. ran tests for more than two years on a turbine-powered, heavy-duty truck. The weight of its 220-lb. powerplant compared with a comparable gasoline engine weight of 1,500 lbs. and a diesel weight of 2,650 lbs. Later the Boeing engine was installed in Firestone tire-testing racer and pushed it to 140 mph.

In March, 1950 the Rover Co. in England built probably the first turbine auto, an open touring car called the *Jet 1* which carried its powerplant in the rear. In 1954 the same firm built a turbine sedan model and two years later repeated with the *T3*, a two-place sports coupe, also with a rear engine. Also British was the Austin Sheerline model, built in 1954 and powered by a heat-exchanger turbine.

In France, Renault built a twin-finned racer, *L'Etoile Filante (the Shooting Star)* in 1956. It placed the driver just behind the front wheels and the engine over the rear axle. And both Mercedes-Benz and Ferrari reportedly have done research and development on turbine race cars.

MATERIALS *for the automobile revolution*

Aluminum — *Entire car, except windows, upholstery, and rugs.*
Cast iron — *Cylinder sleeves.*
Ceramics — *Muffler coatings.*
Dacron — *Tire cords.*
Delrin — *(Possibly) stressed parts such as steering components.*
Hydrogen and oxygen — *Power generating fuel cells for electric cars.*
Nickel — *Die Cast (zinc and steel) trim parts.*
Phosphors — *Luminescent coating for instrument glass.*
Plastics — *Wheels, springs, bumpers, windshields.*
Styrene butadiene — *Tire treads.*
Synthetic lubricants — *For transmission.*
Teflon — *Chassis bearings.*
Urethane — *Filling for non-pneumatic balloon tires; crash padding; floor and seat padding.*
Viscosity index improvers — *Lubricating oil.*

Related to the turbine is the free-piston engine or free-piston gasifier. Basically this is a self-powered piston compressor which supplies gas to run a turbine wheel. So far it has run a GM experimental car, the *XP-500* (as well as a converted *Liberty* ship).

Pistons—free and hot

As developed by GM the engine consists of two opposed pistons working in a horizontal cylinder and actually joined by a trapezoidal linkage — but only to keep them in phase. The inner ends of the pistons operate diesel-style by compressing air to high temperature, then exploding it and bouncing out to opposite ends of the cylinder.

As they move outward, compressing air at the far ends of the cylinder, one piston pushes exhaust gases out through an uncovered exhaust port; these gases spin the turbine. The other piston uncovers intake ports; air rushes in, helping force out exhaust gases and charging the combustion area for another power stroke. As the air at the ends of the cylinder is squeezed to maximum compression, it bounces the pistons back where they compress the combustion mixture again, and the cycle repeats.

A big point in favor of the free-piston design is that because the turbine can be mounted remotely from its source of compressed gases and operate perfectly well on the 900-degree gases supplied by the free-pistons, its turbine blades don't have to be made of the expensive elevated-temperature alloys — as are needed in standard turbines where adjacent compressor stages deliver gases at 1500 degrees F.

About four years ago the intriguing word came over the news wires that a streamlined electric automobile, the *Electronic*, was to be put on the market. It would be built, said the reports, by the Electronic Motor Car Corp., Salt Lake City. It would be powered by an electric motor fed from batteries energized by a gas-turbine generator. The removable fiber-glass top would go on or off in 10 seconds; the car would go 100 mph.

As it turned out, the *Electronic* was never built, but it seems clear that national interest in modern electrics did not die.

The new electric cars

The building of full-sized electric autos ended in the U.S. about 1931;

PERECO*

Carbon-Resistor type TUBE FURNACES

5000°F.

with Precision Controls for Accuracy of Repeated Firing Cycles (plus or minus 20° F or better)

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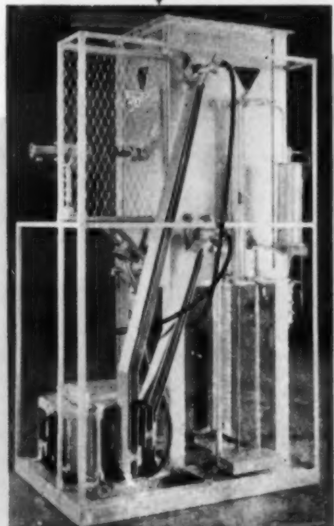

NOW— available in various sizes in both VERTICAL and HORIZONTAL types

- Precision controls with wide-range "turn-down"
- Choice of extremely rapid, or any slower, cycle heat-up
- Interlocking FAIL-SAFE safety devices
- Radiation type controllers and saturable core reactor power package
- Temperature-controllable over exceptionally wide range
- Water-cooled electrodes with "FAIL-SAFE" feature

Pereco Carbon Resistor-Type Furnaces were developed to meet the increasing demands of both industry and military for an approved unit suited for investigations in the ultra-high (3500°-5000° F.) temperature ranges in the field of either metallurgy or ceramics. Units now in use in leading laboratories are daily demonstrating their ability to repeatedly duplicate operating results with the utmost accuracy. Provided with horizontal push-rod ports — or pneumatic elevator-type load bearing column — either straight through or "in-place" firings (on pre-determined schedules) can be readily accomplished. This highly versatile equipment may be just what you are seeking for your high temperature investigations. Write *today* for further details and prices.

It will pay you to keep in touch with Pereco. As part of their development program Pereco is currently working on some revolutionary new advances in ultra-high temperature equipment.

SPECIFICATIONS FOR STANDARD MODEL PERECO "CT" SERIES FURNACES

MODEL	DIMENSIONS					Maximum Connected Load	Maximum Temperature	Approx. Ship. Wt.
	Loading Area		Overall (Approx.)					
	I. D. of Tube	Length	Wide	Deep	High			
CT-212	2"	12"	43"	90"	61"	30 KW	5000° F.	5650 lbs.
CT-312	3"	12"	43"	90"	61"	50 KW	5000° F.	5900 lbs.
CT-412	4"	12"	43"	90"	61"	75 KW	5000° F.	6400 lbs.
*CTV-212	2"	12"	35"	45"	86"	30 KW	5000° F.	5450 lbs.
*CTV-312	3"	12"	35"	45"	86"	50 KW	5000° F.	6100 lbs.
*CTV-412	4"	12"	35"	45"	86"	75 KW	5000° F.	6500 lbs.

*"V" indicates the Carbon Tube is in a vertical position.

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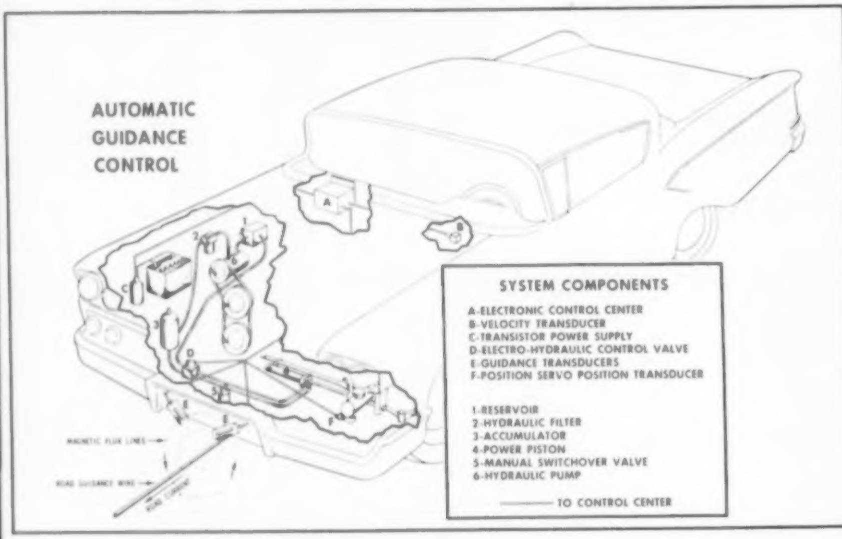
yet in recent years an electric vehicle industry has been springing up again. As of 1957, for example, 30 American manufacturers were turning out an estimated 5,000 electric vehicles a year. True, these were miniature runabouts for shopping and transport across golf courses and through big industrial plants, but the interest and need for electric transportation plainly exists.

Reacting to this interest, several manufacturers have developed electrics, beginning with research and ending with finished, roadable vehicles.

The most advanced project, certainly in point of time, is the Charles *Townabout*, a sports coupe quite remindful in appearance of the Volkswagen *Ghia-Karmann* and built by Stinson Aircraft Tool & Engineering Corp., San Diego, Calif. Weighing 1,875 lbs., it has a fiber-glass body and aluminum frame. Wheelbase is 94½ in. Power is delivered by twin 3.2-horsepower, 3,200-rpm electric motors driving rear-axle jack shafts through reduction gearing (6-to-1 ratio). For comparison purposes, the motors' relative *brake* horsepower figure would be 35. Power for the 49-volt electrical system is delivered by four 12-volt replaceable-cell, selenium batteries in series. Running range is about 80 miles, top speed 50 mph, and price, including charger and built-in reeled cord for 110-volt-outlet recharging, is $2,895.



At the same time, the Cleveland Vehicle Co., Cleveland, has been working on both truck and car projects. Its electric truck number 2 is a polyester-glass-body metropolitan-style delivery model (tested for milk deliveries) which weighs 3,000 lbs. and is powered by a 44-cell battery pack. The car project is a six-seater *Rambler American* which will run to a top speed of about 40 mph. for ranges up to 100 miles. It is to have a fiber-glass body and a six- to seven-horsepower electric motor energized by a lead-acid battery (200-ampere-hours) under development by Philadelphia Industrial Division of Electric Storage Battery Co. Expectation is that perhaps batteries would be rented for both car and truck.

Also making use of an American Motors Corp. *Rambler* is a joint project by that automaker and the Sonotone Corp., Elmsford, N.Y. Stated object of the project is to see whether electric power might lead to more economical autos. Specifically, work is concentrating on development of an electrical power system which would be recharged constantly during running by a generator powered by some type of small engine.

The battery used in this research project will be a Sonotone nickel-cadmium unit of the type used in aircraft and missiles, much smaller and lighter than conventional lead-acid units. It won't freeze even at minus 60 F, can be recharged quickly, handles power overloads, and surges well.

GUIDANCE SYSTEM *developed by GM research laboratories makes use of a servo-mechanism and small analog computer to control automatic steering. Permanent highway cable (top) with a low-frequency charge creates a magnetic field along its entire length. An automobile equipped with the robot control (above) straddles the magnetic field with a pair of pickup coils so tuned that any deviation from the electrical path causes a variation in voltage which activates the computer. A modified power steering unit frees the driver's hands (left) for more important things.*

The new fuel cells

All electrical power doesn't need to come from batteries. An idea car proposed by Chrysler's De Soto Division and called the *De Soto Cella I*, for instance, uses the hydrogen-oxygen fuel cell for power.

Plans call for a lightweight, high-

Lacking automotive birth control legislation, we will have 100-million cars by the year 2000.

speed geared motor to be mounted at each wheel and driving brief, universal-jointed axles carrying the wheels. As in all the electric projects, a major advance over heat-engine powered vehicles would be the dropping of transmissions, propeller shafts, and heavy rear-axles and axle-gear assemblies.

Advanced research on the fuel cell, incidentally, is proceeding both in the United States and in Great Britain. In this country the Patterson-Moos Research Division of Universal Winding Co. is doing basic research on the cell and has teamed with Pratt & Whitney Aircraft Division of United Aircraft Corp., which is studying all systems and components. Both are working with the Bacon fuel cell under license from the British National Research Development Corp.

Patterson-Moos has developed a cell which delivers 500 watts. British developer Francis T. Bacon has developed a cell using porous nickel electrodes. His delivers two and a half kilowatts. Compared to lead-acid storage batteries, for example, Patterson-Moos cell produces 250 watt-hours from one pound of fuel; a battery turns out 10 to 12 watt-hours per pound.

Are wheels passe?

Possibly the most advanced power system coming out of today's revolution in automobile research is levitation, or air-cushion, power. Air-cars don't fly in the usual aeronautical sense. Instead they float or sled along on their own constantly replenished cushion of air.

For the Army's Transportation Research & Engineering Command, Piasecki Aircraft Corp. in Philadelphia has developed an aerial jeep which is propelled by fore and aft ducted rotors. Sometime next year, Piasecki hopes to have a commercial version on the market for about $5000. Chrysler has announced another flying jeep, also developed for the TREC and also with front and rear ducted propeller fans. Powered by a 250-horsepower engine, the car is 23 ft. long, goes 25 mph. The *Air-Car,* built by Curtiss-Wright Corp. and scheduled for production at C-W's plant in South Bend, Ind. this month, will carry four passengers at 60 mph, six to 12 inches aloft. Two engines, totaling 300 hp., drive the car.

For the future, Curtiss-Wright envisions not only cars, but busses, heavy-duty vans, and pickup trucks—and is building prototypes of such vehicles for use on both land and water. On land the *Air-Car* can travel over any terrain which has been cleared of large obstacles with a road scraper; such roads could be built for as little as $500 a mile.

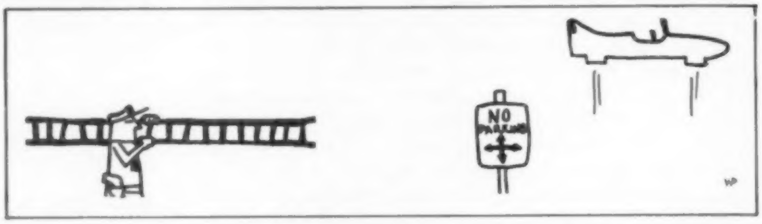
Ford Motor Co.'s contribution in this area is the *Levacar,* probably the lowest-riding of any of the air vehicles. A vehicle of this type, says Ford, could easily go 200 to 500 mph since it would have no friction to overcome.

Heart of the Levacar is the *levapad,* basically a flat round metal plate with a center hole through which air is pushed. This pressure spreads a thin film of air outward, lifting the *Levacar* on a cushion just thick enough to make it levitate.

Developer of the levapad system is Andrew A. Kucher, Ford's vice-president of engineering and research who first proposed the *Levacar* approach to high-speed ground transport in 1928. Kucher, who sees the *Levacar* principle as being most applicable to a type of rail transportation (for levapad stability), does not foresee the end of wheeled transportation. He compares today's high-point of wheel development to propeller aircraft when they were at the peak of their development in such models as the *P-51, Spitfire,* and *Messerschmidt.*

Many other hedge-hopping vehicles either are coming out of the laboratory or already are flying. In Illinois a physician, Dr. William R. Bertelsen, wanted a vehicle for making his medical calls which could travel over ice, snow, water, swamp, or sand, as well as pavement. His solution is the *Aeromobile,* a one-man, ground-effect vehicle powered by a four-cylinder, 72-horsepower McCulloch two-cycle engine. It flies 40 mph at an altitude of six inches. Built of sheet aluminum, plywood, spruce lumber, and steel pipe, construction cost of the *Aeromobile* is $435 with a used engine, or $1,625 with a new one.

Elsewhere, Britain's Saunders-Roe has tested the *Hovercraft,* an air-cushion vehicle that flies 15 in. over land or water at 25 mph. Other air-car work has been done or is underway by Spacetronics, Washington, D.C. (25 ft. long; 100 mph.); National Research Associates (10 ft. long); Princeton University (five-horsepower saucer); Aerophysics Co., Washington, D.C.; University of California; Iowa State University; U.S. Navy's David Taylor Model Basin; Convair Division of General Dynamics Corp.; Carl Weiland of Zurich, Switzerland; and the Gyrodyne Co., St. James, N.Y. (one-man vehicle).



Ramming air into engines

Refinements in engine components and accessories are another area of power advances. While supercharging apparently is not going to be used on American passenger cars in the near future (except for an occasional centrifugal or axial-flow type), a new approach is being used on some models beginning with 1960. The approach is simply to cram more air into the engine. This is the ram-induction technique in which air-intakes are extended and the additional scooped-in air forces more fuel mixture into the cylinders.

Other work has centered on the exhaust system. One manufacturer (Bettinger Corp., Milford, Mass.) is coating mufflers with ceramics to extend their life to 100,000 miles. At the same time, Chrysler and Thompson Ramo Wooldridge Inc., are carry-

ing on joint research to perfect an auto exhaust after-burner. The object is to lessen smog, if possible, by reducing the unburned hydrocarbons and carbon monoxide in exhaust fumes. Ford and GM both are working on catalytic systems to do the same job.

What will automotive power and the rest of auto structures be like in the future? Some have suggested the possibility of nuclear power. Walter Zinn, one of the designers of the submarine *Nautilus*'s atomic power plant, believes we won't be able to overcome the problems of shielding in a car. If we *can*, Dr. Peter Kyropoulos, head of technical development on GM's styling staff, thinks it will be used to run an automotive steam engine.

Jet power is out because it would injure anyone in its wake. Solar power, says Dr. Kyropoulos, is a good idea in principle but is not consistently available nor storable in a compact package. Norman Barnes of General Electric's research laboratory has shown that a 200-horsepower car would need 2,940 square yards of solar batteries to move it down the road.

Will cars replace people?

Probably the most notable thing about the automotive future is not the details of the cars themselves but their sheer numbers. Petroleum scientist Daniel P. Barnard of Standard Oil (Ind.) predicts 100-million of them by the year 2000. Since by now there seems to be no hope for any kind of automotive contraceptive effect, the best way to live with the mass of cars is to adapt to them, and a number of new and proposed developments are aimed at this goal.

Radar locating devices in the twin nose cones of Cadillac's *Cyclone* experimental car will scan the highway, warning the driver electronically about objects in his path.

For similar purposes, an induction-field proximity warning device has been proposed by Richard B. Schulz, electrical engineering specialist at Armour Research Foundation. Radio transmitter and receiving equipment, mounted behind the radiator grill, would trigger a red warning light or loud buzzer at the dashboard to warn the driver in rain, fog, snow, or darkness that he was too close to other vehicles or vice versa.

Partially related to this system in effect is the electronic vehicle control

system developed by Radio Corp. of America. Originally demonstrated in a test installation at Lincoln, Neb., the RCA system guides cars automatically along the highway and gives electrical signals for automatic braking and steering. In addition, the system also can promote highway safety by measuring car speed and flashing "Slower Please" signals to drivers breaking the speed limit.

Similar systems demonstrated by GM are the "auto-control" and "highway information" systems.

"Auto control," designed primarily for limited-access roads, steers, controls speed, and detects obstacles automatically. Command signals given electronically and magnetic reduction techniques come from wires embedded below the highway surface. Car-mounted coils detect these signals.

Another GM development, the "highway information" system, consists of a low-frequency radio setup which automatically transmits oral information or warnings on traffic conditions from roadside to the driver —either via the car radio or a special receiver.

As a safety measure, the highway information system could warn motorists almost instantly about trouble ahead, supplement traffic signs, especially when they are obscured by weather and/or darkness, and it could be integrated with police and highway-department communications.

For use in congested cities, another electronic system, the "electromatic traffic expediter," has been designed by Joseph L. Barker, research director of Automatic Signals Division of Eastern Industries Inc., Norwalk, Conn. The system surveys passing traffic, estimates how well it's moving, then warns monitors when a traffic jam is imminent.

Electronic parking

Parking, a gigantic problem in the United States now, apparently is growing bad in Europe too, and again electronic solutions have given some relief. For example, the "autosilo" automatic garage used in Basel, Switzerland, uses electronically operated cranes and conveyors, push-button operated by drivers, to stash cars away in the upper reaches of its eight floors. The process is reversed when a customer returns, and after the car is down an automatic computer adds up the bill.

Automotive research is a big operation and getting bigger. The American Management Association reports that the auto industry was first among 23 industry groups in increases of research budgets for 1959 over 1958; its rise was 32%.

Here again electronic techniques are being used increasingly in conducting automotive developmental research. General Motors links steering wheels to an analog computer to find out how new cars in the design stage will perform on the road. Also at GM, to avoid the expense of building several prototype engines, engineers used a digital computer in designing the regenerative gas-turbine engine for the *Firebird II* experimental car.

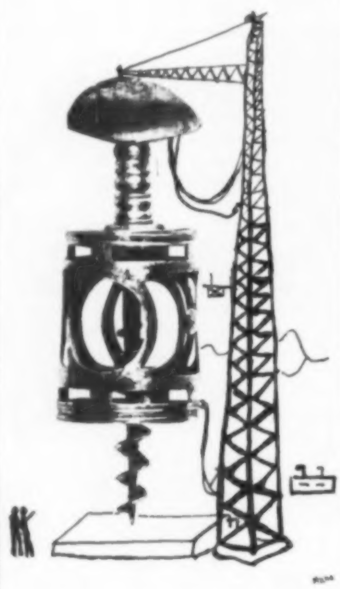
At Chrysler, engineers cut the lead time prior to completion of the first car for the new smaller-sized *Valiant* from Detroit's usual 30-36 months to only 27 months. One of the main reasons for this time savings was the *Valiant* task force's extensive use of IBM digital computers. Instead of building and testing all trial parts and components, designs were tried electronically, sifted out, then the remainder actually were machined. Another use of computers on the *Valiant* was to calculate whether a newly designed part would resonate and become noisy in the finished car. Doing the same job without the IBM equipment, Chrysler says, would have taken dozens of mathematicians months of working time.

The body as a unit

Housing the motorist is a major phase of the automotive revolution. Chrysler is going to "monocoque," or unit-body, construction this year in all brands except its *Imperial*. Reason for the change is that Chrysler engineers — like other unit-body advocates — believe it is the surest way to an ideally quiet, durable sturdy car body. Other approaches to good body design are being tried by other builders.

Kaiser Aluminum and Chemical Sales Inc. has submitted to the auto industry designs for an all-aluminum passenger car (except for windows and fabric parts).

DuPont hopes that its Delrin plastic can be adapted by automakers for the manufacture of stressed parts such as front-end steering units. Also, fiberglass continues a popular if not widely used body material and still shows chances of becoming more generally adapted. Two new foreign



"Now we have nothing to fear from the Russians."

cars, Israel's *Sabra* station wagon and the small car built by Zor-Auto of Canada, will have glass-fiber bodies.

Changes are going on inside too. Alternator-rectifier systems for delivering alternating current seem ready to replace the traditional generator regulation direct-current system. The big advantages of the d-c system are higher current output, lighter-weight units, and the end of burned-out generator coils, brushes, and other moving parts. Ford and GM have been using the alternator system in some of their heavy vehicles; Chrysler probably will introduce it first in passenger cars.

Chrysler also has brought less instrument glare to night drivers with the introduction of electroluminescent instrument lighting on its *Chryslers* and *Imperials*. The new blue-green lighting units, developed by Sylvania Electric Products Inc., will not burn out but rather fade in intensity (service life — more than 10,000 hrs., compared to 300 to 1,000 hrs. for incandescents).

Another instrument advance is the introduction of tiltable speedometers on GM's 1960 models.

Next revolution: materials

Entirely new classes of body and frame materials will be used in the next 50 years, believes Ford's Dr. Kucher. These will include: steels more than twice as strong as today's; plastics as strong as today's metals and used for body panels and load-bearing members; and strong glass-like materials having both strength and transparency and usable for roof construction. With such window roofs it might not be necessary to install the roof periscopes proposed by American Optical Co. for giving drivers a wider, safer field of vision, free of back-seat blind spots.

As the result of striving for more and more advances through research, automotive designers are learning more, are able to do more — because their scientific heritage has deepened. Just as da Vinci wanted to loft himself, so do we in 1959 with our hovering and levitation cars. Against this backdrop it may not be too speculative to envision the realizing of that *desire to lose heaviness*. Already, for example, anti-gravity research has been conducted by such firms as Sperry Gyroscope, Bell Aircraft, and Martin. It might even solve the traffic problem of those 100 million cars. ■

I R RESEARCH FOR THE INVESTOR

Big business R&D budgets are up 12% over last year, with the automobile industry showing the largest gains.

Autos led the research rise among 23 industry groupings with a 32% increase (see *Another Automobile Revolution* in this issue). Other budgets showing significant gains of more than 20% were instruments, electrical machinery, and metalworking machinery concerns, according to the AMA.

Research spending averaged 3.2% of sales, overall — the rubber industry leading with a 9.3% R&D reinvestment. Two industries, foods-beverages and paper, showed less than a 1% of sales research expenditure.

What may be a record in research spending was announced by the Magnavox Co., which turned over *12.4%* of its sales dollar to the development of new products, airborne communications, radar, and data-handling equipment.

Electronics

Increased research expenditures to keep abreast of new technological developments is being blamed in part for lower profit margins in the electronics field.

In the highly-competitive (some 80 firms, 40 of which have entered the field in the last three years) semiconductor market, for example, product obsolescence is a constant bugaboo. Labs around the nation are turning out new materials and gadgets so rapidly that firms have difficulty getting back development costs from sales.

Semiconductors now sustain a $1-billion market, but forecasts indicate this will be chopped in half within a few years. Thus, many companies probably will merge or fail.

Announcement of the construction of a new plant near St. Louis heralds the entry of Monsanto into the chemicals-for-electronics industry. Research in silicon is underway, and Monsanto is getting a license to use the Siemens-Westinghouse process for making ultra-pure silicon.

Metals

Expansion in R&D facilities characterizes the metals industry today. Two companies have announced additions to their present research plants, Alcoa, with a multi-million dollar research center at Merwin, Pa., and Foote Mineral, with a new $2.2-million research and engineering building at its present center near Exton, Pa.

The long and costly steel strike was not without benefit to the industry itself, as it enabled several companies to continue installation of new basic-oxygen converters, said to be the greatest technological advance in steelmaking since before 1900.

Developed from the Swedish Kaldo process, the furnace employs a direct stream of high-purity oxygen to burn off impurities instead of the open-hearth's external heat. Advantages: lower capitalization, operational savings, faster production.

Now there are only 12 of the new converters in operation in the U.S.: McLouth Steel of Trenton, Mich. has five, Kaiser Steel three, Jones & Laughlin two, and Acme of Chicago two. These account for a little more than 2% of total production, but indications are they'll handle as much as a quarter of the nation's steel by 1965.

Jones & Laughlin is so enthusiastic about its two converters at Alquippa it has contracted for a $24-million oxygen plant at Cleveland. Colorado Fuel & Iron will install a shop at Pueblo, and Phoenix Steel plans one for Burlington, N.J. Great Lakes Steel, Armco, Republic, and others have the process under study.

The atomic industry

Chief gains in the relatively new field of nucleonics have been in radioisotopic analysis. The AEC reports that industry is saving more than $1-million *daily* by the use of isotopes. Companies with new or expanded facilities for their industrial application are Evans Research & Development Corp. and Nuclear Consultants Corp.

Less spectacular but gaining steadily is the field of radiation processing, employing beta or gamma rays above one kilowatt in power. Not yet a tool of major importance because of their present high cost and limited advantages over other radiation sources, radioactive nuclides hold promise for the next five-to-10 years.

Two new profitable applications are the sterilization of surgical sutures and cross-linking of polyethylene in various shapes. A handful more are in the testing stage, but most will be expensive, low-volume specialties.

The military is experimenting with it in food sterilization and pasteurization and it is hoped that by 1970 it will be useful in increasing the shelf-life of rations by several years.

(continued on page 34)

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For additional information circle No. 17 on the Readers' Service Card.

Research for the investor *(con'd from page 32)*

Chief R&D areas ahead for radiation processing: "cheap" radiation and the discovery of processes where radiation will provide the only feasible approach.

In the nuclear-fuel industry current stockpiles of mined and milled uranium ores already are some 20 years ahead of industry requirements.

Best investment opportunities until the industry catches up with its suppliers should be in the refining of mill concentrates (U_3O_8) into chemically-pure uranium compounds, reprocessing of "used" materials (including the recovery of usable elements and the disposal of radioactive wastes), and fabrication of uranium into fuel elements.

Refining today is done chiefly in two large government-owned plants, one operated by the National Lead Co., another by Mallinckrodt Chemical Works. Fabrication is private, principally at General Electric, Westinghouse, Olin Mathieson, and Metals & Controls.

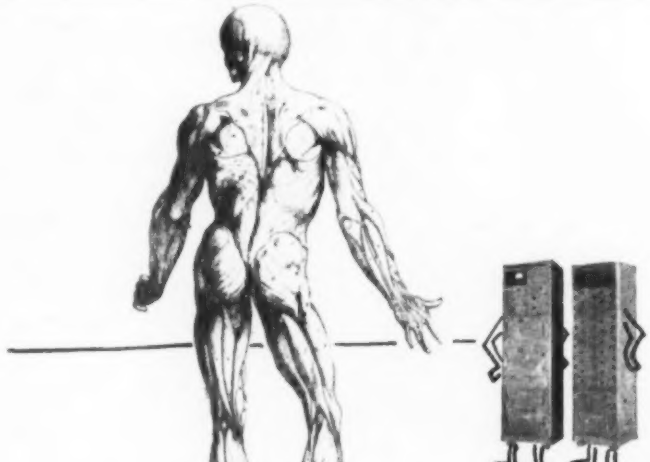
Because of hazards involved in reprocessing and the limited market for high initial investment, the government so far has not been able to interest private industry in this phase of fuels-handling. Currently it owns plants operated by Phillips Petroleum Co. and Union Carbide Nuclear Co.

A more specific use of nuclear fuels is not now economically feasible. In spite of the Navy's success with marine application and our "showboat" merchant ship *Savannah*, technical obstacles are still too great to interest private industry. Established companies supplying nuclear fuels now (like Sylcor or Metals & Controls), however, are of some investment interest.

Spacecraft

Recent breakthroughs in space technology have spurred activity throughout the industry and the resulting expansion and construction may be of interest to the investor:

- The newly-established Space Technology Division of Aerojet-General (subsidiary of General Tire) is engaged in R&D on ion and nuclear propulsion and space systems. Among the projects in which Aerojet is participating are *Dyna-Soar, Thor-Able, Vanguard*, and *Aerobee.*
- An Avionics Flight Test Center has been set up by Texas Instruments near Dallas to bring together labs, engineering offices, and airport facilities for more efficient testing of airborne electronic systems.
- CBS Laboratories and M. Steinthal & Co. Inc. have cooperated in creating a new concern, Space Recovery Systems Inc., to research recovery methods for personnel and equipment from high altitudes and outer space. Steinthal long has been a leader in the parachute and recovery field.
- Recent contracts from the AEC and Navy Aeronautics Bureau necessitated expansion of technical ceramics production at Gladding, McBean & Co., an R&D leader in developing rocket nozzles, radomes for the *Sparrow III* missile, and solar furnace components. ■



"It's complex, but will it work?"

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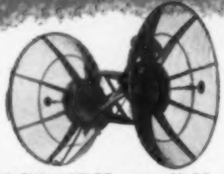
another way to say
"COMMUNICATIONS"



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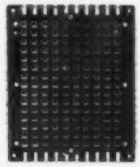

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Today, Kellogg systems and components play expanding roles in remote control, data and voice transmission, telemetering, microwave–for Kellogg is the *communications* division of International Telephone and Telegraph Corporation, pioneer in communications developments.

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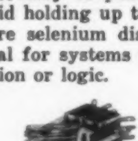

RELAYS For all industrial needs, fitting a wide range of applications. Kellogg will gladly engineer relays to meet any specific requirements.

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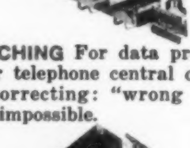

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MILITARY R&D

Washington, D.C.
4th quarter, 1959

Dear Sir:

The technological crisis that has developed between the U.S. and USSR hinges upon a margin of superiority in research and development. New knowledge is not exclusive to any one area of the world. Eventually, both sides could enjoy the benefits of such advances. The important points are: when, and in what order?

For instance, when will a significant breakthrough in high-temperature metals be made? In the period of tension today, this factor of lead time (the period from wanting to getting, from "womb to boom") assumes strategic importance.

Today, U.S. lead time is about eight years for research, development, testing, and production. When compared to the Soviet lead time of about five years, we can see that government and industry have a critical problem to solve.

This means Russia can beat us to the punch on items that we ourselves conceive. For example, if a technological breakthrough were achieved today, it would not be until 1967 or later that a new family of developments could be operational.

> In contrast, the USSR could acquire such new information even two years later, and still beat us to the punch by one year with a new weapon or counterweapon. This is why we are so conscious of the need for a drastic revision of our funding and management techniques to achieve a cycle of four years.

What can industry do to achieve such a cycle? The rapidity of new inventions and breakthroughs requires a studied alertness to utilize these developments. Such information must be assimilated and disseminated quickly. Concurrent engineering research and production design is necessary—the "systems engineering" concept.

The government also can help cut lead time by improving decision-making in the evaluation of new weaponry. One important goal should be termination of unprofitable projects.

Early production tooling is crucial in extending our time scale. We need a greater capacity for rapid conversion and re-equipping military production lines with modern tools already stockpiled or available from consumer goods production.

In accomplishing military production objectives, economic resources are important, but cannot be substituted for foresight. Our military budget experience makes that clear.

> Large appropriations made after the Korean war in fiscal years 1951 and '52 did not produce any significant expansion in deliveries of either standard or advanced hardware until the conflict had terminated. The funds provided <u>before</u> conflict erupts spell defeat or victory in any war of less than three to five years duration.

Herein lies the significance of lead time in this era of big budgets. We certainly cannot buy time with money when expenditures lag requirements by a period of years, particularly in wartime.

Our procedures are too rigid and restrictive. Acceleration of deliveries usually can be accomplished only on a crash basis—which still involves additional changes, disruption of normal procurement procedures, and unacceptable delays. However, with some of our critical missile systems, planned telescoping or a high degree of overlapping in the phasing of programs now is the rule.

> In some 14 missile projects, this has reduced lead time to five years, eight months— a highly significant improvement. A further decentralization of authority would have a beneficial effect in broader fields.

But despite our disadvantage in lead time, research has made rapid advances for military development. Research contracted to industry and universities is the chief determinant of the state of the weapon art during the next decade and beyond.

Applied research programs have resulted in improved rifles and other small arms. Many types of guided missiles are under development to supplement or replace those we have now. For instance, <u>Sergeant</u> will replace <u>Corporal</u>, and <u>Pershing</u> will replace the workhorse of our missile arsenal <u>Redstone</u>. In addition, <u>LaCrosse</u> units now being organized will back up frontline infantrymen. These are all surface-to-surface weapons fired at ground targets.

Missiles, space vehicles, and even tanks will benefit from industry's advances in high-temperature alloys and electronic miniaturization. Research by Army engineers recently resulted in an AC-DC inert gas arc welder for hard-to-weld thin gage materials for support of the Army's missile program.

In the air defense field, the shoulder-fired missile Redeye will be used against attacking aircraft; the field mobile Hawk missile will be employed against low-flying aerial targets. We have successfully fired the sustainer rocket motor for Nike-Zeus (the only weapons system presently designed to attack incoming ballistic missiles) and are now getting along into the testing stage of the complete system. In the future we hope to fire it against our own IRBMs and ICBMs to establish its effectiveness. NASA and ARPA are undertaking studies to speed detection of ballistic missiles.

On the ground, battlefields of the next decade would be much larger than ever before—with less clear-cut boundaries between units. Real mobility will be the key to success. Combat units will move fast, concentrate to destroy the enemy, and then disperse rapidly. Soldiers will move in aerial vehicles just above the "nap" of the earth and carry with them new types of lightweight but potent weapons using conventional as well as atomic ammunition.

Some interesting vehicles are under development to give troops the mobility they require. On the ground we look to the "Goer" type of equipment used in the construction industry, where large wheels and tires give true, off-road mobility. New tanks and armored personnel carriers will back up the powerful new weapon systems.

One unique vehicle is a highly mobile airborne mechanical ditch digger, being tested by Army Engineers. The digging mechanism is hydraulically retractable for road travel (at 35 mph) or air transport. It can dig 12 feet of trench a minute.

The search continues for efficient Verticle-Takeoff-Landing and Standing-Takeoff-Landing vehicles that will fly low, slow, and quietly just above the battlefield.

Communications and electronics have enabled the Army to increase its command and control capabilities to the degree required by mobility and dispersion. New radios and relay systems will use the latest techniques of earth satellite transmission and of bouncing signals off the moon. Included in this area

also are the surveillance drones that will penetrate enemy lines to send or bring back information recorded by radar, infrared, photographic, and TV equipment. This information then will be sorted and evaluated by automatic data processing systems.

> One Army-Air Force experiment has shown that closed-circuit television—with camera and receiver at plotting boards—can speed exchange of radar information between the two services. Detection information is expected to be relayed 84% faster.

But in the highly competitive field of international technology the U.S. is lacking sorely in several areas. We should seek a greater coordination of effort within friendly nations by fostering coordinated development programs. Research, development, and production engineering procedure must be streamlined and funded to gain the maximum benefit of current technological advances.

Industry must gear itself to produce items of complexity and performance previously unknown—in an absolute minimum of time, with full consideration of the man-machine compatibility problems involved.

In turn, government must streamline its time-honored, but time-consuming, administrative procedures.

Lt. Gen. Arthur Trudeau
Chief, Army R&D

New Industrial INFRARED Device Measures...Controls Temperature...Without Contact

Since World War II, there has been an accelerated development of materials and components for infrared guidance and reconnaissance systems. A number of components and techniques, developed for military use, are now being applied to industrial instrumentation. Radiation Electronics Company has developed several types of infrared instruments for remote temperature measurement and control now being used in the production and testing of paper, glass, rubber, metals, and plastics.

The Thermodot radiation thermometer, Model TD-3, has been designed specifically for production plant operation. Since the operation is completely remote, Thermodot readily measures and controls the temperature of moving and inaccessible surfaces. The high sensitivity of Thermodot provides reliable measurements at low temperatures—the lowest standard range is 400°F full scale. Other standard ranges extend to 2000°F. Measurements are completely automatic and continuous, and the response time is two seconds. An internal calibration source provides rapid and accurate standardization.

Thermodot measures the temperature of a remote object without physical contact. Operation is based on the fact that an object emits thermal radiation as a function of its temperature. An infrared lens, located in the Thermodot optical head, is used to focus this radiation onto a sensitive infrared detector. The detector generates a signal voltage accurately proportional to the radiation intensity, and the signal is amplified to drive an indicator calibrated directly in temperature.

The infrared radiation detecting element is hermetically sealed to prevent contamination by vapors and fumes. In addition, the optical assembly is housed in a sturdy, dust-tight enclosure and is insensitive to vibration and shock as normally encountered in the plant. Ambient temperature variations from 20-120°F have no effect on its operation.

Complete Thermodot Model TD-3 Consists of Optical Head, Power Supply and an Indicating Controller

SPECIFICATIONS OF THERMODOT MODEL TD-3

WORKING DISTANCE . . Any range greater than one foot (prefocused at factory).

SPEED . . . . . . Responds in two seconds.

CALIBRATION . . Internal reference source permits accurate standardization in seconds.

EMISSIVITY COMPENSATION . . Adjustable at control panel.

AMBIENT CONDITIONS . Unaffected by ambient temperature variations from 20-120°F.

For more information, write for Bulletin R-100.

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Stimulus to business extension:

space technology

THE USE OF ARTIFICIAL SATELLITES: A SOVIET PERSPECTIVE

A USSR-eye view of how artificial satellites can be applied in peace and war, by one of Russia's foremost space scientists. Politics are conspicuously absent from his practical ideas.

THE DREAM WORLD OF SPACE

The space business today is a bandwagon with scientists, businessmen, and other types jumping on. Here, some fantastic assumptions about space are separated from realistic goals.

SIMULATING SPACE

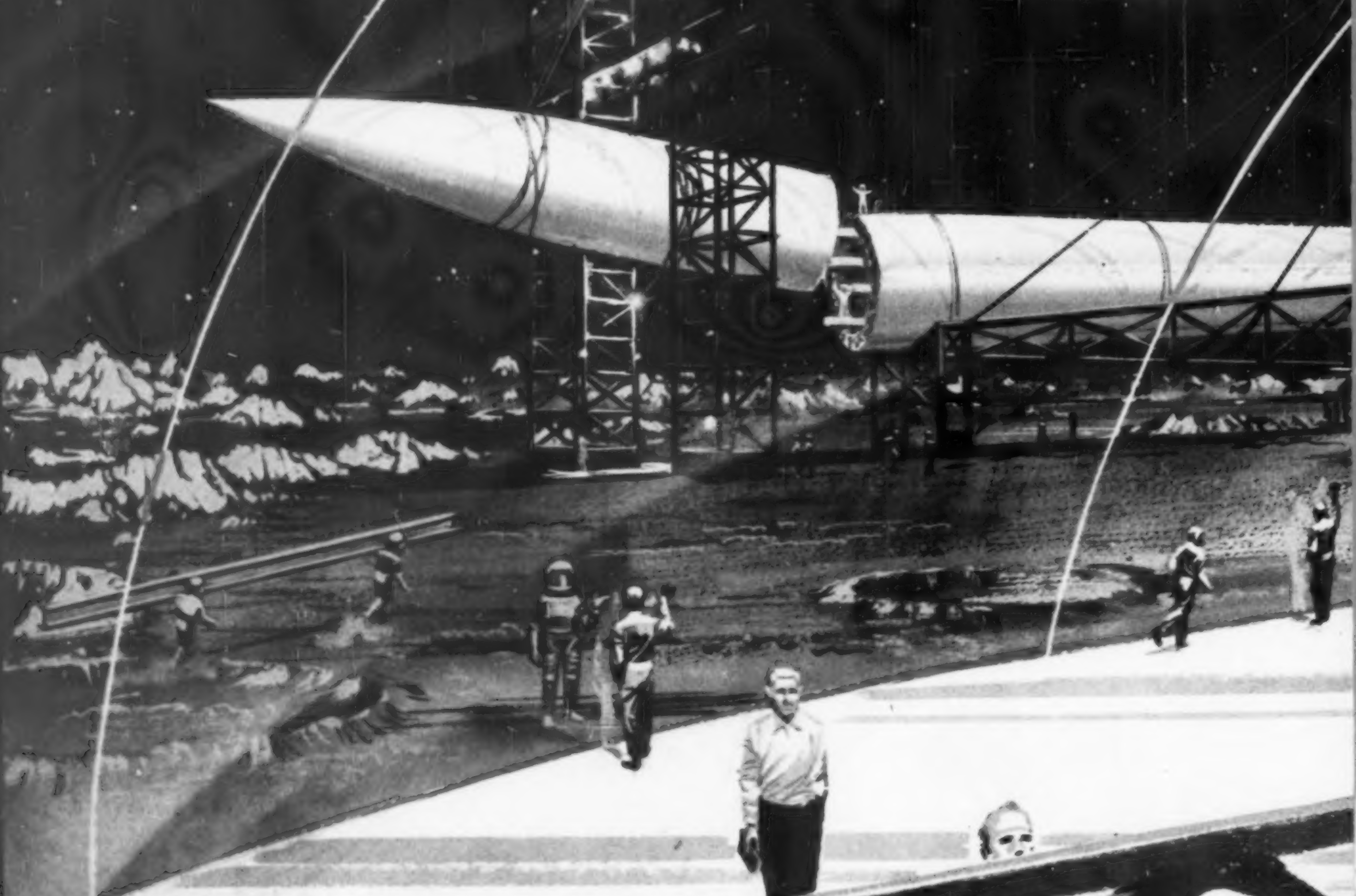
How technical problems of space exploration can be solved before man actually lands on the moon or planets. Cabinets today simulate a remarkable variety of environments.

THE ROCKET: A PAST AND FUTURE HISTORY

A revealing rocket history that couldn't stop. The "history" starts with the ancient Greeks, carries through the present, and explores the future of man's space machine.

The author, Ari Shternfeld, is one of the world's foremost space scientists. Some 30 years ago, Robert Esnault-Pelterie of France, then a pioneer in aviation and later also in rocketry, helped establish an annual prize of 4,000 francs for the best contribution to the science of "astronautics," a word he coined. The first award went in 1928 to the German mathematician Hermann Obert. In 1934 it went to a "Monsieur Ari J. Shternfeld." Since then, Shternfeld has been working intensely

the use of artificial satellites:



The next space-step, after artificial satellites and the recent moon landing, may be a base on our natural satellite. Assembling rockets on the moon will save fuel because of the weaker lunar gravity; vehicles could shuttle between the moon and other natural satellites, never entering an atmosphere or a high-G environment. If the scene above becomes a reality, astronomical, geological, medical, and physical research will be among duties of the scientists pictured. Does artist Palm depict them as Americans. . . or Russians?

in this field in France and the Soviet Union. The book from which this chapter is condensed and updated stands as one of the best surveys of the state-of-the-space-art published in any country. Sputnik I proved not only the validity of Newton's laws but also the dangers of insularity. Willey Ley, in his forward to Soviet Space Science, *suggests we acquire the habit of paying more attention to Russian professional literature so that future surprises, at least, will not be so surprising.*

by **Ari Shternfeld,**
the USSR's winner of the International Prize for the Promotion of Astronautics

a soviet perspective

ILLUSTRATED BY FELIX PALM

Circling the earth in daylight 114 times a week,
one satellite could photosurvey many unexplored areas.
The width of the Atlantic Ocean can be determined
with an accuracy of 100 feet.
Satellites will detect gravity deviations, find reserves of natural resources,
warn navigators of ice packs, discover forest fires, forecast weather,
calculate densities of the upper atmosphere,
and study the earth's magnetic field and cosmic ray intensity.
In the polar orbit to the right, routes are only 3°9′ apart.
A similar lunar orbit could map
the moon's entire surface in less than a month.

During recent years the term "artificial earth satellite," which had an unaccustomed ring, has been encountered with increasing frequency. Today, the artificial satellite is no fantasy or daring dream, but a tangible achievement. It was the first step toward our successful flight to the moon, and will lead to future flights to the planets.

Theoretical substantiations for the possibility of creating an artificial body to revolve around the earth appeared as far back as 1687, when the brilliant work by Isaac Newton, ***Mathematical Principles of Natural Philosophy***, was published.

At the very beginning of the 20th century, K. E. Tsiolkovskii proposed "setting up a permanent observatory, to revolve around the earth beyond the limits of the atmosphere, like its moon." But conditions necessary for solving so complex a problem as the creation of an artificial satellite of the earth did not then exist. It has only been in our day, when science and technology have made immense strides forward, that the solution of this problem has proved feasible.

The artificial satellite combines the properties of balloons capable of hovering above the earth for a long time, and of rockets capable of rising to high altitudes. From an artificial satellite, man for the first time will be able to see the earth suspended in space. Artificial satellites are useful primarily as flying observatories for inspecting the surface of the earth or moon, the data automatically recorded and transmitted to earth by radio. We here present some examples:

A remarkably unpolitical and detailed elaboration of this article may be found in author Shternfeld's newly translated book, Soviet Space Science, *published by Basic Books Inc., 59 Fourth Ave., New York 3 ($6; 361 pp). Information presented here is an updated condensation of the book, especially of chapter 11, "The Utilization of Artificial Satellites."*

The moon unmapped

Now that we have reached the moon, the idea of a satellite orbiting at low altitude around the moon becomes feasible. An artificial satellite revolving around our natural satellite could be established in an orbit six miles above the surface. That would be close enough to provide a detailed look, but high enough to avoid crashing into lunar mountains, some of which reach five and a half miles high.

Of course, the absence of an appreciable atmosphere makes such a low orbit entirely practical. The low altitude will be equipped with television and other devices to transmit map pictures of the moon to the earth.

The lunar satellite would be launched from earth to a point 120 miles above the moon. There it would be given an automatic sidewise thrust to move it into the proper orbit, which would grow closer and closer to the moon until it would pass into a circular path at the proper altitude.

Traveling in a polar orbit, the satellite could survey the entire surface of the moon in less than one month.

The earth unmapped

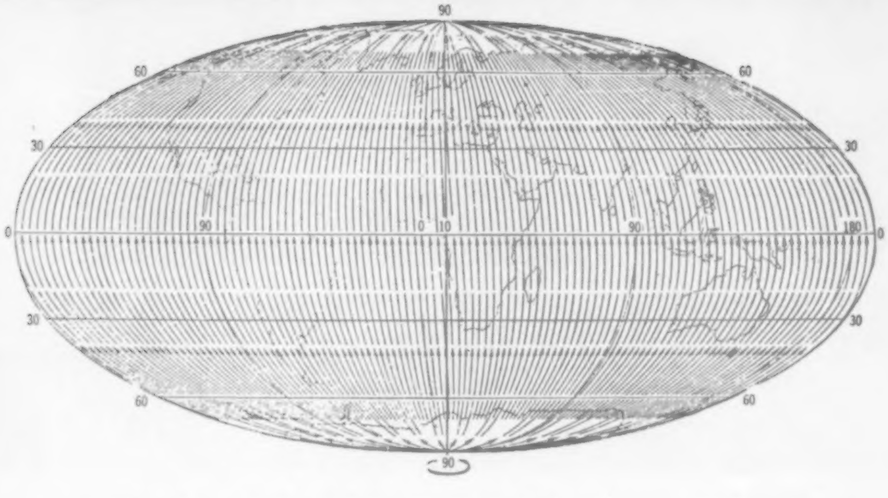
At the present time, high precision cartography of the continents has covered only 7% of the land surface of the earth. From an artificial satellite, however, it will be possible to map, by photosurvey, many of the almost inaccessible localities.

Large areas covered by clouds can be photographed by means of invisible infrared rays as well as by means of radar. Photographs of the earth's surface taken from an artificial satellite will be distinguished by high accuracy. Distortions due to the atmosphere will be negligible. The effect will be like reading a printed text through wax paper.

Television transmitters can send simple and stere-

If man can pinpoint a rocket to the moon, he can pinpoint an

When that man is a Russian, it pays



oscopic views of the surface of the earth (or the moon). To obtain stereoscopic images, two transmitting television cameras can be placed on two separate satellites and the distance between them maintained approximately constant during their motion, or, one satellite with a single camera can make photographs at different moments of time.

Exact observations of the motion of artificial satellites, even of very small size, permit very precise measurements. For example, the width of the Atlantic Ocean can be determined *with an accuracy of 100 feet*. In this way, the artificial satellite will make it finally possible to confirm or refute the hypothesis of the relative shift of the continents.

During observations of the motion of satellites, it is possible to detect gravity deviations connected with the nonuniform structure of the earth's crust, which possibly may permit the discovery of petroleum deposits and other useful minerals.

Although aircraft make constant observations of the movement of the floating ice in the Arctic seas and oceans and patrol forest expanses, such observations will be considerably more efficient from artificial satellites. The instruments installed on them will warn navigators of ice packs and will report back to the earth on forest fires.

Glaciologists hope that observations from an artificial satellite will confirm the hypothesis that the earth's climate is becoming gradually milder and that, in this connection, the ice cover of our planet gradually is retreating.

At least 1% of the water mass of the earth is ice, which covers 1/10 of the earth's surface. But in the distant future, water from melting ice will raise the level of the world's oceans and submerge some of the ports existing today.

Satellites revolving in elliptical orbits permit a three-dimensional magnetic survey of the space surrounding earth, can study the causes of magnetic anomalies, investigate the effect on the earth's magnetic field of the electric currents generated at very high altitudes, and study the influence of the variation in cosmic ray intensity on the course of magnetic storms. Of practical importance, such studies will permit the discovery of mineral deposits and determination of their ore reserves.

Our knowledge of the atmosphere's upper layers is still incomplete and demands fundamental deepening. In particular, scientists are attracted by the problem of measuring the pressure and density of the high layers. Methods based on the ionization of a gas have been worked out to measure a pressure of the order of one-billionth of a millimeter of mercury. Knowing the mass, dimensions, and shape of the satellite, it will be possible to calculate the value of drag experienced by a satellite in its motion and, finally, to determine the density of the air from these data.

Sodium weather forecasting

Artificial satellites soon will be useful for meteorological observations and weather forecasting. Periodically a satellite could eject sodium vapor, which becomes strongly luminescent in the rays of the sun. From the degree of dispersion of the sodium train it will be possible to judge the temperature of the upper layers of the atmosphere, while the change in the shape of the sodium "cloud" will serve as a basis for determining wind velocity at a given altitude. The satellite makes it possible to track the spread and movement of clouds, to define the boundaries of warm and cold air masses, and to measure the spread of storms.

The hypotheses that atmospheric oxygen results from the decomposition of water vapor under the action of solar rays into its constituent chemical

ICBM to Chicago.

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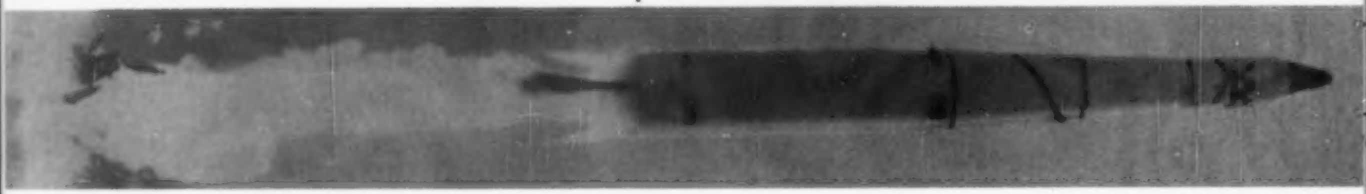
2

1



elements (with hydrogen flying off into space and oxygen remaining on earth) can be tested. It is possible to study ionization of the atmosphere at various altitudes and forecast conditions of radio communications.

Micrometeorites seem to affect the state of the ionosphere and thereby also the propagation of radio waves. Artificial satellites already have begun to establish the distribution of micrometeorites and also the variation of their impulses and electrical charges with geographic latitude. An artificial satellite may be made completely airtight and filled with gas under pressure before launching. A drop in gas pressure will mean a puncture of the satellite skin by a micrometeorite. The curve in pressure as a function of time will indicate indirectly its size and velocity.

World-wide radio, TV

Satellites will play a direct role in radio and television transmission. Because of the complexity of the instrumentation and the need for strong sources of electrical power, such use is not envisaged for the immediate future. But a stationary spherical satellite for relaying ultrashort waves would be 1,000 feet in diameter. Three such relay stations would be sufficient to maintain communications over 90% of the earth's surface.

From earth's surface we cannot solve the problem of whether our planet, together with its atmosphere, is electrically charged or neutral. This can be elucidated only on an artificial satellite flying beyond the boundaries of the atmospheric envelope of our planet. At the same time it will be possible to measure the earth's radiation.

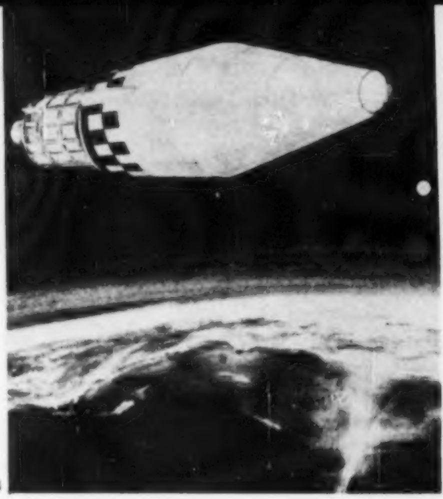
Artificial satellites also can be used for studying "cosmic dust" of interplanetary space that is produced in the collision of meteors with small planets. This dust, which scatters the sunlight, is composed of particles larger in size than those of interstellar dust or "cosmic smoke."

Meteoric bodies of known shape and composition can be ejected from a satellite, thus yielding abundant data on the nature of natural meteorites and of the conditions of retardation of spaceships by the atmosphere. We will know not only the velocity of entry of the meteor body into the atmosphere but also its path from the instant of launching. Meteorites will be visible from an artificial satellite, not against the background of the sky, but against the background of the earth, submerged in the darkness of night.

As soon as an orbital rocket is flying beyond the boundaries of the sensible atmosphere,—that is, one or two minutes after take-off—the celestial vault will lose its usual blue color and will become black. Absolute darkness never occurs on earth since sunlight is scattered by some degree throughout the atmosphere.

The appearance of the sky will differ completely from its appearance seen from the ground. To our eyes, most of the southern celestial vault is invisible, just as the northern celestial vault is invisible to inhabitants of the southern hemisphere. The entire celestial sphere will be visible during the course of a local "day" (that is, during one revolution around the earth) at the altitude of an artificial satellite and there will be no atmosphere to distort observations. The untwinkling stars will be distinctly visible.

Under such conditions, photographs of the planets and their satellites can be taken at any desired magnification, while in earth observatories even an 11-X magnification causes trouble because of the optical "vorticity" caused by the atmosphere. Moreover, the astronomical optical observations on an artificial satellite will not depend on caprices of weather.



3

From the launching pad into orbit, the U.S. Discoverer satellite is powered first by a Thor ICBM (1), *then by the small but powerful Bell Hustler* (3). *Blast from the liquid-fueled Hustler lights the night sky in a test firing* (2). *The 1,300-pound Discoverer will carry biomedical specimens for space research. Researchers also could utilize satellites as astronomical observatories in space and for experimental verification of the theory of relativity. Satellites can measure the earth's radiation, and also answer the question of whether our planet is electrically charged or neutral.*

A Soviet Palomar in space?

Instead of constructing a giant new observatory on the earth (like the observatory on Mt. Palomar in the United States) it would be better to make use of an artificial satellite for this purpose. It would be cheaper to construct and would yield more important discoveries. Television transmitters would permit ground observers to view the sky seen by outer-space telescopes.

The opportunities for astronomy in radiations outside of the visible spectrum will be expanded greatly. These waves will be detected before they penetrate into the atmosphere. While the visible light of the sun is almost constant, its ultraviolet light fluctuates over a wide range; from this point of view the sun resembles a variable star. The difference between the spectra of the solar radiation at the earth's surface and beyond the exosphere indicates the spectra absorbed by the earth's atmosphere. A continuous determination of solar and earth radiations will permit a periodic establishment of a radiation balance for our planet. The relation between solar activity and the ionization of the atmosphere also can be determined.

The artificial satellite also is useful for studying cosmic rays in space beyond the atmosphere (for example, their content of atomic nuclei of lithium, beryllium, boron, etc.). Data on cosmic rays transmitted from the second Soviet artificial satellite distinctly showed the dependence of the number of particles of cosmic radiation on the geomagnetic latitude (the latitude with reference to the magnetic poles). American satellites have discovered two doughnut-shaped bands of trapped cosmic particles.

Tables of the positions of artificial satellites may find uses in navigation. Variations in the distance of a radio receiver from a satellite would vary the frequency and intensity of radio signals received. One method for determining coordinates of ships and aircraft uses three polar satellites revolving at low altitudes in planes mutually intersecting at 60° angles. A pound of strontium-90 and any yttrium isotope is sufficient to supply power to the radio for 20 years.

Clues to relativity

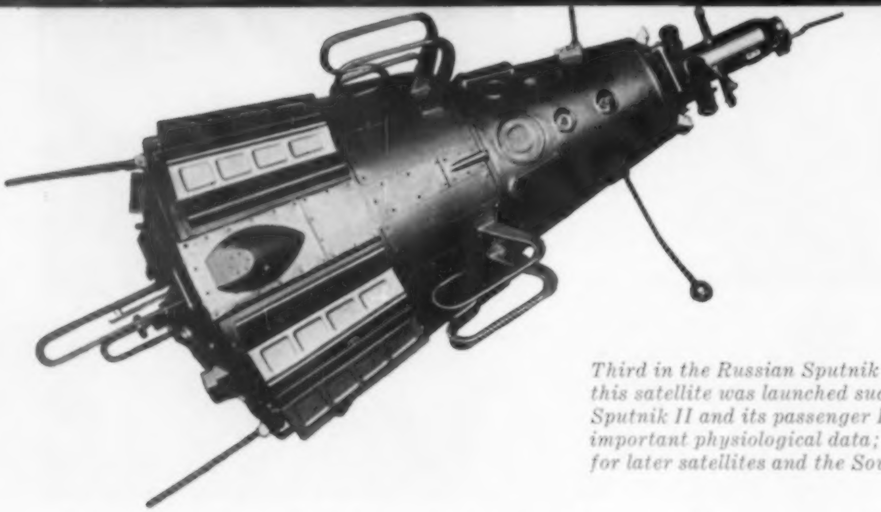
Artificial satellites will permit an experimental verification of the general theory of relativity. According to this theory, a gravitational field slows or accelerates photons, depending on whether the attracting body emits light or, conversely, is exposed to light directed toward it. As a result, the frequency of the electromagnetic oscillations (that is, of light rays or radio waves) will decrease or increase respectively.

Thus, if a light ray sent out from a satellite is passed through a prism on earth, a shift of lines toward violet should be detected in the resultant spectrum. However, if such a ray were sent from earth to the satellite, a shift of spectrum lines toward the red would be expected on the satellite.

Also, according to relativity, a clock on an artificial satellite should run slower, as the velocity of the satellite increases. This can be checked by means of a so-called atomic clock.

Research workers on board an artificial satellite will have available extreme vacuum and low temperature conditions for work on superconductivity, etc. It is possible that under the conditions of weightlessness, crystals will grow more rapidly and even change their structure; in this manner, the range of available piezoelectric crystals will be augmented.

Therapy on an artificial satellite under conditions of weightlessness possibly might be indicated for certain heart diseases, to ease the blood pump's struggle against gravity. On an artificial satellite it



Third in the Russian Sputnik series, this satellite was launched successfully in 1958. Sputnik II and its passenger Lika provided important physiological data; Sputnik III made investigation for later satellites and the Soviet moon launchings.

will be possible to verify the hypothesis expressed by Tsiolkovskii that plants and organisms, from the simplest to the most complex, will grow and develop far more rapidly under conditions of weightlessness than in the presence of gravity.

Satellites for war

Questions related to the use of artificial satellites attract the attention of politicians as well as scientists. An artificial satellite of minimum dimensions would be invisible both by day and night. It could be utilized for military inspection of enemy territory, preparatory work for testing atomic weapons, deployment of an enemy navy, construction of industrial plants, etc. Even the take-off of an aircraft from an aircraft carrier could be detected.

From an artificial satellite, bombing could be conducted with matchless accuracy. The guided missile designed for bombing would be ejected by the aid of a rocket engine. The instant of ejection would be calculated so that when a missile reaches its perigee, the bomb target would be in the optical or radar sights.

Thereafter, visibility not only of the target but also of the missile from the satellite would improve. The satellite, moving through practically airless space, would rapidly overtake and overfly the missile, which would be subject to air resistance.

The missile thus could be guided with an accuracy impossible for ground control. Such a satellite, however, is very difficult to build and easy to shoot down. Its high velocity and the insufficiency of fire of an anti-aircraft rocket do not make it invulnerable. A missile of shrapnel type—launched into the satellite's orbit to meet it head-on—could destroy it.

From the viewpoint of astronautics, the use of artificial satellites will be of greatest significance. The influence of weightlessness on physiological and psychic processes could be studied on such a satellite, as well as the action of cosmic, solar, and other radiations on living organisms not protected by earth's atmosphere.

What the space dog showed

Such experiments actually were staged on the second Soviet artificial satellite. The fact that a living organism was able to function for several days under conditions of weightlessness allows us hope that man also will be able to survive a space journey.

There is no velocity that the human organism could not endure, provided that it is not accompanied by excessive acceleration. In fact, does the earth's rotation about its axis disturb us even to the slightest extent? On the equator, the peripheral velocity of objects on the earth's surface reaches 1,000 miles per hour. Does the earth's motion around the sun at a velocity of more than 60,000 mph disquiet us? Do we, finally, notice at all the motion of our entire solar system in cosmic space, at the velocity of 43,000 mph?

To reach Venus and Mars, our nearest planetary neighbors, a spaceship—as did the Soviet moon rocket—has to develop a take-off velocity of seven miles per second, more than 13 times the speed of sound. To facilitate interplanetary travel, Tsiolkovskii proposed utilizing an artificial earth satellite as

Soviet experiments with animals have advanced the hope that man also can survive a space trip. Two pioneer space travelers—the dog Daring and the rabbit Snowflake—were passengers on the USSR's one-stage geophysical ballistic rocket.

Satellite stations one day even may be assembled in space. Completed station (lower right) contains hydroponic gardens on its sun-exposed rim, solar batteries mounted on bracing wires, and a shaded observatory atop its vertical axle. A ferry ship carries prefab parts for the ferry "dock" at the lower axle. The final stage of a ferry rocket leaves its multi-cluster booster (upper left). Such a station would have its own seasons and day length. In take-offs from the satellite, astronauts could stand and move freely, because only low-power thrusts are necessary.

a peculiar kind of transfer station, thereby dividing a space journey into stages. Here the cosmonauts could supply themselves with everything necessary for continuing and completing their space journey: fuel, equipment, provisions, etc.

A spaceship, as well as various cargo necessary for reaching the ultimate objective, first may be delivered to such a station in separate parts. This will facilitate the spaceship's design, since for take-off from the platform, the ship will need a considerably smaller fuel supply than for take-off from the earth.

Satellite escape: 2mps

A major advantage of such an intermediate station is its mobility. A rocket capable of rising from earth to an altitude of 620 miles could reach Venus or Mars—if it started out from an interplanetary station. Thus, to take off from a satellite for these planets, a rocket will have to develop a velocity of only two miles per second, instead of the seven mps from the ground, since the station itself already has a velocity of five mps. A rocket that can achieve slightly more than five and a half mps on dispatch from the satillite could leave our solar system entirely.

In some versions of spaceship design, the interplanetary station also can be used for the return trip. Here the crew would transfer to a space glider, on which it then would land on earth.

The unavoidable heating of a flying device in motion at very high speeds through the air, however, will lead necessarily to hazards. The example of "shooting stars," which become heated to incandescence on penetration into the atmosphere, shows that the landing of a device with an artificial satellite on earth is a complex problem.

Low-flying satellites with circular orbits are more advantageous for manned flights to the moon and planets than satellites moving at greater altitudes. In the former case a smaller total velocity is necessary for flight from earth to the satellite and for proceeding, from the satellite, on the farther space trip.

On take-off from an artificial satellite, physical conditions on board the spaceship will be completely different from what they were during a take-off from the earth's surface. For example, the astronauts will be able to stand and move around freely without effort. Their weight, due exclusively to the thrust of the low-power rocket engines, will be insignificant.

The satellite will have its own seasons, due (as on earth) to variation in length of day and night. However, on earth changes in the length of day and night during the course of a year are caused by the inclination of earth's axis to the ecliptic. On an artificial satellite they are caused by the varying duration of time spent by the satellite in earth's shadow. The longer a satellite remains in the shadow, the lower is its mean temperature. Nominal winter on the satellite is the period of longest nights, and summer the period of longest days. On satellites that rotate rapidly about their axis, a practically constant temperature might be established on the entire satellite.

We now present a concrete project for the utilization of an artificial satellite as an interplanetary station.

Von Braun's spaceship

According to a combination project proposed by Wernher von Braun in the U.S., an artificial satellite moving at an altitude of 1,150 miles would be used as a station point for two ships with a crew of 12 to be dispatched to Mars. One of them would be an automatically guided cargo rocket which will not return to earth. Each ship has an initial weight of 1,700 tons, of which 1,246 tons are to be fuel, and is equipped with 12 rocket engines, each with a thrust of 30 tons.

After 260 days, the ships, entering the gravitational field of Mars, retard their motion by the aid of rocket engines and become artificial satellites of the red planet. From one ship, nine astronauts leave for the surface of the planet by means of a glider, while three remain on the satellite base.

After two years, 239 days, from the time of take-off from earth, the expedition returns to our planet, after first making a stopover at the interplanetary station. The landing is accomplished on space gliders. The return to earth, like the flight to Mars, is accomplished on a semielliptical trajectory, but lasts only 260 days.

To prepare for this expedition to Mars, it would be necessary first to ferry, from the earth's surface to the satellite, 3,720 tons of payload, using 400 orbital supply rockets.

Unrealistic projects are also being advanced, alongside such serious ones for using satellites as the above example. It has been proposed, for instance, that immense mirrors be set up near artificial satellites to reflect solar rays to earth. This type of reflector, it is claimed, could heat large areas of the globe, melt the ice, and change the climate of the Arctic and Antarctic.

For the construction of such "space mirrors" entire rolling mills would have to be carried aloft! Sodium billets brought to outer space would have to be rolled to a thickness of one five-hundredths of a millimeter(!) and coated on the shadow side with a suitable composition, in order to maintain the mirror temperature at a level to preserve sufficient elasticity and mechanical strength. By means of hinge systems, the mirror would be assembled on an immense base of sodium wire.

Components of the mirror would be oriented remotely by means of electric power. In this case, each hectare of structure, together with the reinforcement and observation chamber, would have to weigh per unit area about one-fifth that of writing paper! Solar-power engineering has not made much progress in using mirrors even hundreds of times heavier on the earth, where the structures are not menaced by meteors and meteoric dust.

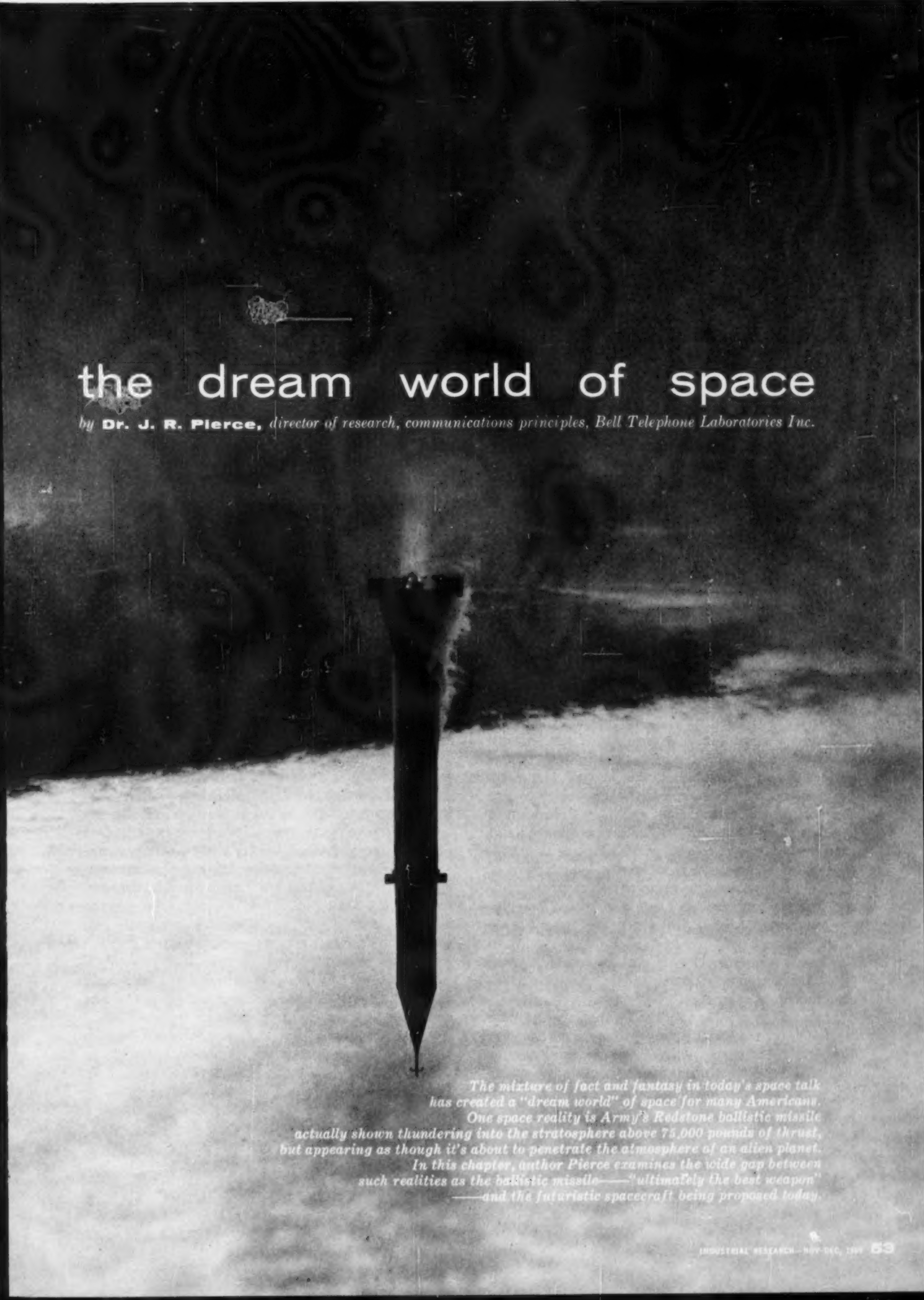
A still more absurd idea is that space mirrors reflecting back the sun's rays might serve to shield the tropics. The idea of using space mirrors to light large cities might be more realistic, since the surface of the mirror, at least, could be millions of times smaller.

The moon as a station

In the literature on astronautics, assertions are made that the moon can be utilized as an interplanetary station. Actually, it is unsuitable for this purpose. It is too far from the earth's surface and its gravity is too high. A rather large amount of fuel would have to be expended during the descent to its surface and then for take-off. A second natural satellite of the earth, even if it were exceedingly small, still would be an important step toward penetration of man into cosmic space. The discovery of such a satellite would facilitate considerably the solution of the problem of manned flight to the moon and planets, and would make the construction of an artificial satellite necessary.

Mankind now has entered the era of interplanetary flight.

Laws of nature favor the development of astronautics. In aviation, new altitude records demand increasingly greater efforts and are confined to the atmosphere's boundaries. In astronautics, the ceiling limited by nothing, and equal successive increments of velocity will lift rockets to ever increasing heights. For this reason, the dispatch of automatic rockets to the nearest planets is possible even in our own days. We already have seen their dispatch to the moon. ■



the dream world of space

by **Dr. J. R. Pierce,** *director of research, communications principles, Bell Telephone Laboratories Inc.*

The mixture of fact and fantasy in today's space talk has created a "dream world" of space for many Americans. One space reality is Army's Redstone ballistic missile actually shown thundering into the stratosphere above 75,000 pounds of thrust, but appearing as though it's about to penetrate the atmosphere of an alien planet. In this chapter, author Pierce examines the wide gap between such realities as the ballistic missile——"ultimately the best weapon" ——and the futuristic spacecraft being proposed today.

Breaking icons about space travel does not come easy for Dr. John R. Pierce. Pierce has been, and still is, all for solving the staggering technical problems of space. But in this article he puts his foot down, heavily, upon those who have confused speed-of-light ships, antigravity, maneuvering in space, etc. with achievable reality. Pierce received his Ph D in 1936 from California Institute of Technology and joined Bell Telephone Laboratories that same year. After holding posts as director of electronics research and director of electrical communications research, he was promoted to director of communications principles research in 1958 — a field including radio, electronics, acoustics, vision, mathematics, and group behavior. Pierce has won the IRE Fellow award for contributions to vacuum tubes, the Eta Kappa Nu (outstanding young electrical engineer) award, and the IRE Morris Liebmann Memorial Prize. He is the author of The Theory and Design of Electron Beams, Traveling-Wave Tubes, Electrons, Waves and Messages, *and* Man's World of Sound.

Like many squeamish Americans, I enjoy a gory mystery novel hugely, but I would be shocked and disgusted to find a corpse in my living room. Even more then whodunits, I like science fiction, and few stories are too fantastic to entertain me. I thrill to the thought of cutting down an Eddorian[1] with a Delammeter[2]. I accept a Bergenholm[3] or a space warp[4] as a convenient means of interstellar travel. But, like other canny fiction fans, I don't confuse these things with the world around me, any more than I think of Mike Hammer or Santa Claus as real.

Today, I am shocked by space talk.

When corny and long-disproven fallacies of space travel appear and reappear in seemingly respectable newspapers and journals, no one so much as lifts an eyebrow. Indeed, the way to fame appears to be the propagation of the big error, and a fantastic story suffers only from the competition of one still more fantastic.

Today, a great deal is known about our physical world which is as true in space as it is here on the surface of the earth where it was learned. For many years astronomers have known the laws which govern the motions of planets and satellites. There have been many experimental verifications of the behavior predicted by special relativity. The laws of the propagation of radio waves are known. The power of chemical fuels is known. From newspaper reports of the failures and successes of missile and satellite shots we know a good deal about the present state of the technical art.

What do these sources of real knowledge tell us about the present and future of the exploration and exploitation of space?

They tell us most emphatically that a great deal of what people say with a straight face is the sheerest fantasy. Take travel with velocities approaching that of light, for instance, which involves the much discussed "twin paradox."

Special relativity tells us that a clock whizzing past an observer will appear to him to run slower. Years ago, Ives verified that molecules moving at high speeds radiate lower frequency, redder light than they would if they were stationary; this shows that they vibrate more slowly when traveling fast.

Mesons going with almost the speed of light last longer than slower mesons do; time passes slowly for them, and they take longer to disintegrate. We can take it as an experimentally verified fact that clocks appear to run more slowly on swiftly moving objects.

The fantasy of the 'twin paradox'

One might think that this would lead to a paradox: *I* say that *you* are moving past me, and that *your* clock runs slow. *You* say that *I* am moving past *you*, and that *my* clock runs slow.

However, in order to come back and compare clocks a space traveler must turn around, both with respect to the earth whence he departed, and with respect to the light and radio signals that are traveling toward him from earth. Because of this turning around, the space traveler's experience is just plain different from that of the stay-at-home on earth.

You may utter many different sorts of words concerning this, but all that are consistent with relativity describe the same fact. Thus, when careful calculations are made concerning a journey into space and back again, no paradox appears, and the unusual conclusion is as follows:

Suppose one twin stays on earth and another sets off at 99.5% of the speed of light on a journey to the stars and back. Suppose the earth-twin ages ten years before the star-twin returns. When the star-twin gets back he has aged only one year though his brother has aged ten.

The first point to make is that relativity assures

[1] *An evil race.*

[2] *A weapon of the future.*

[3] *An inertialess drive — a polite way of getting around certain physical laws for literary purposes.*

[4] *Another literary device for evading the limitations of relativity and making rapid interstellar travel possible.*

us that each twin has experienced the usual physical laws and a normal environment in every way. I once heard a rumor that a doctor wanted to study the effect of relativistic shrinking on organisms, but I hate to believe that any scientist could be informed so poorly.

The second point to be made is that we can't expect in any foreseeable future to attain anything close to the velocity of light. We have all heard that a mass m is equivalent to an energy mc^2. When uranium-235 is fissioned a thousandth of its mass is turned into energy.

Imagine, now, that we could turn *every bit* of some sort of hypothetical space-ship fuel into energy (what an explosion!). The weight of fuel needed to attain 99.5% of the speed of light would have to constitute 95% of the initial weight of the space ship—and this just to get started. To stop would use up 95% of our remaining 5%.

Counting also starting back and stopping again on earth, our space ship would have to be 99.999375% fuel at the beginning of the trip, and we would have to turn this fuel into energy 1,000 times as well as is possible in a fission bomb.

In the first place, we can't do this and the prospects are dim. In the second place, would a passenger be likely to survive?

What is the truth about relativistic *time dilatation*, or slow-running of fast-moving clocks? At satellite speeds we may in the near future hope to observe the effect by using an atomic clock which makes an error of perhaps one second in a thousand years. Moreover, with such a clock you also could observe an effect predicted by general relativity, but not yet clearly verified: that a clock lifted up against the force of gravity would run faster. This same effect would cause a *red shift* in light from the sun or from other stars.

At attainable space speeds, such time effects are barely detectable, not practically important. And the attaining of speeds at which such effects might become important belongs to the realm of fantasy, not of science and technology. Here I might observe that the newspapers recently expressed concern about micrometeorite impacts at near-light speeds. This is like Bluebeard worrying that he may not be able to endure the ennui of heaven.

Anti-antigravity

If nothing else did, the nonsense written about relativity might make a casual reader suspect some other things which are said in connection with space. Antigravity, for instance.

Respectable physicists are seriously concerned about gravity. They wonder, for instance, whether inertial and gravitational mass are exactly the same (no experiment has shown any difference), and they propose experiments at the very limit of observation.

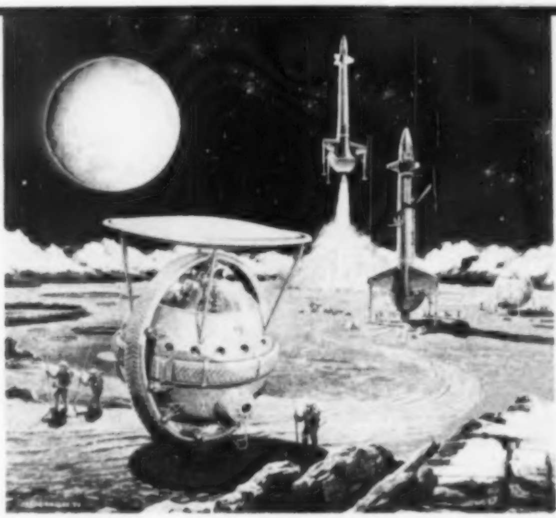
If a very brilliant physicist of recognized competence wants to work on gravity he will, and if he needs money he should have it. To give money to less than the most brilliant for gravity research, and to expect results, makes me think of the man who took a running jump off a Chicago pier. He assured the rescuing policeman that he hadn't meant to commit suicide. Someone had bet him a million dollars to one that he couldn't jump across Lake Michigan, and of course he couldn't afford not to try.

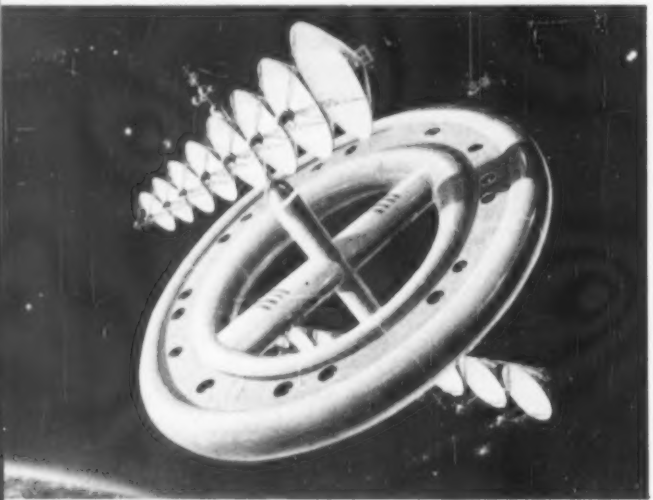
Among the more modest fantasies, that which makes my blood boil and steam issue from my ears is the maneuverable manned space vehicle for military purpose.

Of course we must have sensible research on how to make and control faster and faster and higher and higher planes and even planes that get above anything but the most tenuous and vacuum-like part

An ionic-propelled spaceship, envisioned by Lockheed scientists, converts nuclear power directly to electrical energy. After vehicle is boosted into space by a large chemical rocket, reactor heat "boils" electrons and transmits electricity through the cable. The mile-long cable separates craft from reactor, as protection against radiation.

Definitely of "dream-world" category for some time are the proposed manned space station (below) and moon colonization (right). The space station idea is supposed to be part of a network in permanent equatorial orbit. The moon-explorer surface vehicle in drawing to the right is a gyro-stabilized unicycle of inflated fabric parts. Its "umbrella" top contains solar-actuated batteries.





ILLUSTRATIONS BY FRANK TINSLEY

of our atmosphere. I'm for research on space vehicles too, but let's not pretend that this has anything to do with defense.

It isn't that I don't thrill to the thought of Flash Gordon pulling back on the stick and zooming away from the Perelandrian space pirates; it's just that I know that such goings on are appropriate only in comic strips (they were ruled out of most science fiction years ago).

Why not maneuver in space?

Modern aircraft travel so fast that an unaided pilot could scarcely detect, let alone shoot down, an enemy aircraft without the most sophisticated electronic aids.

Speeds will be much greater in space. Maneuverability will be less, because one can't turn by pushing against the air (there isn't any). Fuel will be in short supply, so that it is only by using the most ultra-advanced guidance that one can get a payload to the desired point in space, and hopefully, in the not too distant future, to get it back again. All we need to louse things up completely is a skilled space pilot with his hands itching for the controls.

Of course, maneuverable space vehicles of a sort are in the building. These are anti-missile missles, which are shot at other missiles and maneuvered toward them by means of radars and computers on the ground. The problem is very difficult but perhaps not insurmountable; the cost is great and may be prohibitive, but the stakes are tremendous.

What about nuclear energy for space flight?

It has possibilities for interplanetary ships, if the nuclear vehicle is first boosted up out of the atmosphere by chemical rockets. In this case an atomic pile would be used to produce electricity and the electricity would be used to eject ions at high speed and so to push the vehicle gently forward over a long period of time. Solar power and solar sailing (propulsion by light pressure on huge metal foil or metallized plastic sails) are strong competitors for interplanetary travel. All of this lies far in the future.

How far in the future? It is impossible to predict times when the technical problems are not even understood let alone solved. Such prognostications are the source of the chronically slipping schedules which have been the most prominent feature of our military space program. Or is the most prominent feature the cheerful acceptance of failure that could have been foreseen? In any case, however far in the future interplanetary travel by ion rockets or solar sailing may lie, they have no important military potentialities.

For every pound of man we put in orbit with chemical rockets, it takes between a quarter of a million and a million pounds to get him there and back. Still, chemical fuel offers a better potential than nuclear for a long time to come.

Chemical missiles are the ultimate

Militarily, earth-launched ballistic missiles are not only the nearest but are even ultimately the best weapons, and chemical fuels are adequate for them. To launch a rocket from the earth calls for an intense if brief push, which present chemical fuels can attain. Atomic propulsion is a hazardous and somewhat dubious alternative which at best could compete only in the rather remote future.

It is easy to arrive at the conclusion that the fantasy and folly of space are limitless, but the space provided on these pages is not. Something should be said about the importance of space.

Certainly, intercontinental ballistic missiles rank first in importance. From a military point of view, who wouldn't give away all the rest of space if only he could have twice as many highly reliable intercontinental missles as any potential enemy?

At present, some but not all intermediate range missles appear to be in fair shape. Good guidance is available for them and for intercontinental missles as well. Bad guidance exists too, and by a sort of Gresham's law of space tends to displace the good, just as bad money displaces good money. As for intercontinental missiles themselves, there is much talk about missiles for the day after tomorrow, which we certainly won't have for many years, and a shocking failure rate in tests of what we hope are the missiles of today and tomorrow, the days which make me, at least, shudder.

This is alarming from the point of view of defense. It is discouraging from the viewpoint of many other military and non-military uses of space. Right now, the reliable (by contrast only) missiles available for satellite launchings can put up only very limited payloads, and allow in most cases only primitive and rather unsatisfactory guidance. Many useful payloads and the full exploitation of the very accurate guidance which is available call for highly reliable boosters of at least intercontinental missile size.

What to expect of space programs

What we can hope to see under present circumstances is a continuing increase of our scientific knowledge through satellite and simple space probe experiments and, in the fairly near future, some simple forms of satellite communications. We also will see a lot of elaborate failures and a senseless peopling of space with mice, monkeys, molds, and axolotls.

When we have big and reliable rockets, and when a lot of time and money have been spent in developing positioning and orientation gear of assured reliability and life, highly useful satellite communication systems of some sophistication will become possible. Whether economically or not, these could provide high quality telephone service to all parts of the world, and television as well. If things go as they have, such useful systems will be preceded and delayed by the slipping of unrealistic schedules and by senseless ventures with equipment of dubious reliability.

A step beyond such advances lie effective reconnaissance and weather observation satellites. A step further lie lunar and planetary probes capable of transmitting detailed pictures back to earth.

The course of man in space also depends on the development of highly reliable big rockets. I can't believe that we'll shoot men up until we are virtually certain that there will be no failure—that is, until the reliability is much higher than the abort rate of military aircraft in World War II, for instance. And, we are far, far from even that degree of reliability. Once given reliability of large rockets and of electronic equipment, men may brave the radiation and micrometeorites of space, with what results we

cannot yet hope to foresee. Some of the prognostications about micrometeorites are rather gloomy.

But all of this lies in a future to which we cannot attach a date, a future in which we have diligently accomplished that which we have neither done, nor, in many cases, (some aspects of reliability, for instance) set out to do. Happily, the National Aeronautics and Space Administration has inherited a great skill from its predecessor and kernel, the National Advisory Committee for Aeronautics. The NASA understands how to carry out and contract for advanced research and experimentation. Further, NASA has been speaking and behaving about as sensibly as the Congress and the public will let it.

Since the military aspects of space are the more urgent today, a check list is provided below, in which importance or sense is indicated in descending order from top to bottom. Items below the heavy rule range from marginal to crazy.

1. Intercontinental ballistic missiles

A must. Existence and reliability are the first criteria. A more refined missile may be nice but it won't kill an enemy any deader. Protection of launching sites from enemy attack is a strong third, but most of all we need operable missiles.

2. Satellite communication

Simple forms of satellite communication might solve some important military communication problems in the near future. Elaborate systems which will not be useful at an early date could cause no end of waste and trouble.

3. Anti-missile missiles

To try is a must, but effectiveness is still uncertain and cost is great.

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4. Reconnaissance satellites

These are definitely submarginal because they will not really be technically feasible until many vehicle and reliability problems have been solved (when will that be at the present rate?). In the meantime a fraction of the cost of a reconnaissance satellite could accomplish wonders in conventional information gathering.

5. Maneuverable manned space vehicles

An interesting and inevitable idea with no military value, except perhaps for reconaissance in the far future.

6. Space platform or stations

Little military value, but will probably come to be, no one knows when.

7. Base on the moon

It's much cheaper and easier to hit an enemy with a ballistic missile launched from the earth. Such a base would have no use as a telephonic communication relay site; the moon is visible only half the time, and the transmission time (ten seconds, round trip, before you can get an answer to a question) is too long.

8. Black magic

This is more promising than the two items listed below and would be so much more fun.

9. Antigravity

Strictly for the birds.

10. Velocity approaching the velocity of light

A fantasy strictly for immature science fiction.

Reader, for whom does the cash register ring? It rings for you; the money that is squandered on space is yours. Worse, every dollar foolishly spent ties up the time of someone who might be making a contribution to national defense. ■

is larger than k_2. In this case the shift is toward less basic research and more applied research. If k_1 were greater than k_2, the shift would be in the opposite direction.

If the A. D. Little surveys are correct —that the actual ratio of k_1 to k_2 is about 2—then the optimum fraction of basic research in a large program to develop a field should be in the neighborhood of 30%—a much larger effort in basic research than is now the case.

IR research on research

(continued from page 7)

People and money

While the model may help research management determine a healthy balance between basic and applied research, the fact remains that our basic research potential is limited not by funds but by competent people. Some interesting facts uncovered by the Little research indicate:

- The people who perform basic research in this country have several characteristics in common—they possess intellectual insatiability; almost all have doctorate degrees; and they're exceedingly rare in number.
- Of the 2% of college graduates who get a doctor's degree in science, only about one in five combines the creative skill and motivation to remain in basic research.
- Only half of these have outstanding talents for the work as indicated by the fact that they produce some 80% of resulting scientific papers.
- The U.S. today has only about 27,000 basic research scientists, of whom about 15,000 are particularly active.
- Dollars for basic research come somewhat more from industry than from government. But the basic work is *performed* primarily by educational institutions, with industry a close second and government a poor third. (The Navy, incidentally, has one-quarter of the R&D budget of the Department of Defense, yet accounts for some two-thirds of the basic research activities performed in government labs.)
- As for where applied research and development is performed, industry accounts for an overwhelming 72% compared to 18% in government laboratories, or 8½% in educational or nonprofit institutions. The money for this applied work comes almost entirely from government (52%) and industry (44%).

For a comparision of practices in

government (specifically the Navy) with those in industry, the research researchers studied 10-year trends in 33 leading corporations, representing the source of almost one-fifth of the nation's and half of industry's total basic research funds.

It was discovered that, while the Navy compared favorably with industry in 1947 when it devoted 10% of its R&D budget to basic research, industry since has outstripped the Navy in emphasis on basic research.

This has come about largely as a result of the growing realization by industrial management of the importance of communicating with that portion of science which creates the knowledge resulting in major technological advances. Put in another way, *applied research and development tend to proceed more rapidly, and at lower cost, when adequately backed by basic research.*

The Navy operates today in a fiercely competitive field having a high technological obsolescence rate. Some 80-100% of ships, aircraft, and missiles scheduled for purchase in 1959 were of types not in existence in 1955.

Thus, for more meaningful basic research guidelines, the Navy should be compared with corporations in high technological obsolescence rate industries. Two of the most successful corporations in chemical, petroleum, communications-electronic, pharmaceutical, and materials were studied.

These 10 firms had a minimum of 10% and a maximum of 20% of their R&D budget allocated to basic research. The average was about 16%, or more than double the present Navy figures of 6 to 8%.

Of course the armed services cannot be compared directly with industry. Being second best in national defense today represents a risk far greater than faced by any corporation. While the consequences of turning research off and on—with disruptive effects on program and organization—are harmful in industry, they are drastic in the military.

The U.S. competitor

One principle held in industry is that a firm should never do less basic research than its strongest competitor. When applying this concept to the U.S. government, the competitor is the USSR.

Soviet political leaders are credited by a number of investigators with a greater knowledge of science than ours, and a greater appreciation of its role in furthering the progress of a nation. This disparity is not confined to government circles; indeed, the percentage of ministerial-rank persons having a scientific or technical education is higher than that found at the management level of most top corporations in the United States.

In fact, the USSR appears to be the first nation to appreciate fully the importance of science. This is evident in many areas such as the vast effort in technical education, the high percentage of gross national product expended on R&D, the important stature accorded scientists in the Soviet society, and the large program to collect, translate, and disseminate scientific publications.

Back of the recent Soviet technological successes is a program of basic research staffed by approximately the same number of scientists as that of the United States. Whenever such a situation occurs, the nation which places more emphasis on a particular field of science will tend to lead in that field.

While overall comparisons have many shortcomings, it appears that currently the United States leads the USSR in most areas of physics, mathematics, medicine, and chemistry; is on a par in aviation and space medicine, metallurgy, combustion, theoretical physics, meteorology, and oceanography; and is behind in physical chemistry and many areas of geophysics, says A. D. Little.

The important problem, however, is the future. Currently the Soviet is training persons capable of performing basic research in science at a rate approximately 50% greater than the United States, while essentially keeping abreast of the U.S. in granting doctorate degrees in other fields. Thus, the Soviet potential is increasing relative to ours at an alarming rate. ■

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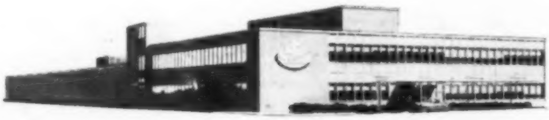

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Write in confidence directly to Dr. Theodore Theodorsen,
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REPUBLIC AVIATION

Farmingdale, Long Island, New York

by **Alexander I. Newman,** *president, Hudson Bay Co., Environmental Division of Labline Inc.*
and **Robert J. Dennis,** *chief liaison engineer, Inland Testing Laboratories Division of Cook Electric Co.*

simulating space

Explosion chamber tests whether electronic assemblies will ignite in a volatile atmosphere as could be found under certain conditions on a spaceship or on another planet.

Down through the thick white clouds, under huge, slowly rotating propellers, floats a bullet-shaped object the size of a washing machine. Small windows in the steel capsule capture light from the hot Venusian ground below. A highly-developed television camera forms this light into an image. The multipurpose propeller blades brake the descent of earth's first instrument package on its sister planet, turn the electrical generator, and serve as antennae to beam back to eager scientists 25 million miles away their first pictures of the shadowy Venus terrain.

Like the automaton it is, the space capsule also measures and reports the intensity of cosmic rays, the strength of the planet's magnetic field, and such facts about its atmosphere as temperature, pressure, and composition. In short, the instruments tell men on earth

Five years ago the description above would have been considered fantastic, in the realm of science fiction. Today, Venus is within the range of our rockets, and indeed, may have been reached by the time you read this. The propellered capsule is in fact the concept of National Aeronautic and Space Administration scientists.

To make sure such flights are successful on the first expensive try, rocket designers are attempting to anticipate and provide for the hostile environments of outer space. To keep rocketeers and rockets functioning perfectly, as they must during such high performance, the designers have to know the reactions of every organ, every subsystem, every capacitor, every valve before the rocket ever leaves its launching pad.

Performance = subcontracts

On a more practical level for industry, reliable performance under extreme missile environments has become a major factor in the awarding of subcontracts. This means that every part that goes into a space vehicle should be subjected on the ground to the identical tortures of flight. The alternate is to fire test rockets to see what will malfunction. With the cost of each Cape Canaveral blast-off averaging more than a million dollars, the alternative becomes prohibitively expensive. A million dollars will buy a lot of environmental testing. And with manned vehicles, such an alternative is out of the question.

In recent years, chambers have been developed to duplicate and maintain every conceivable kind of environment, singly or in combination. Environmental testing has become a science.

Environmental science probably began with development of the greenhouse. Here tropical and subtropical plants could be kept warm in northern climates and artificial light supplemented the short days of winter. While biology got an early start in environmental control, the mass testing of materials under simulated conditions did not come until World War II. With global warfare a reality, the same equipment had to operate in conditions of extreme variance.

It was discovered, for instance, that Allied trucks in the North African campaign often broke down when grease from their wheel bearings, made thin by the addition of desert heat to friction heat, leaked through the wheel seals. From tests of various viscosities and compositions at high temperatures came the development of heavy-duty, high-temperature lubricants—lubricants that also could withstand the rigors of an Arctic campaign.

Applications—mundane . . .

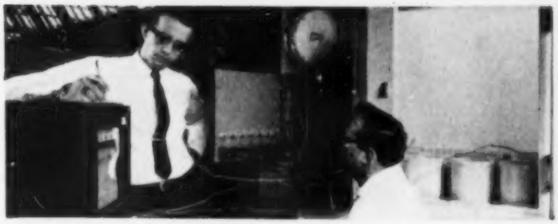
Today, controlled environments are used for a host of mundane as well as dramatic purposes. Examples on the mundane side:

- Englander Co. Inc. tests polyurethane foam mattresses under high humidity to determine in a short time their aging characteristics.
- Constant temperature-humidity rooms are used to evaluate air conditioners by both Underwriters Laboratories and Consumer's Union Inc.
- Diodes are tested at 70 F for component matching in critical electronic circuits built by Hoffman Electronics Co. of Evanston, Ill.;
- Plant growth rooms, in which light, temperature, and humidity are controlled, assist in evaluating fertilizers and in selecting plant strains by the Tennessee Valley Authority.
- Corrugated paper is tested for strength under various climatic conditions by Ace Carton Manufacturing Co.
- Sewage disposal products are tested by most cities with the help of warm, high-oxygen atmosphere chambers.
- Samples of all equipment bought by the U.S.

At this point in the space business, it's easier to build a

what things are like on Venus.

With this knowledge, scientists will program environmental chambers to duplicate all of the conditions to which man and machine will be subject on a flight to Venus. With a giant Venus Room, hardware even now can be designed and built to explore a new world—just as the Santa Maria *was designed and built to explore its New World.*



Environmental cabinets are used at Labline Inc. for humidity aging tests of polyurethane foam rubber, "grass factories" in fertilized water, or "atomic farms" to grow medicinal plants and to extract radioactive drugs for tracer experiments.

Navy are tested for 50 hours in salt-water sprays to simulate the corrosive effects of sea environment.

. . . and dramatic

On the dramatic side:

- Scale models of ballistic missile nose cones are subjected to reentry temperatures of 25000 F through the use of souped-up electric arcs at General Electric.
- Nose capsules designed to carry a man are dropped into the sea near Langley Field, Va. from 75-ft. cranes to determine their water landing characteristics.
- Tests of the effects of intensive radiation on various components of all types are helping in the design of nuclear-powered aircraft, missiles, and rockets.
- Satellite transmitters are tested in grounded rooms to ascertain the inherent self-interference of components.
- The probabilities that electronic assemblies will ignite explosive fuel and air mixtures are derived with the help of explosion chambers.
- The effects of icing on external missile parts are determined with hypersonic wind tunnels that blow moist, supercooled air.

Controlled environments have other uses than testing. An example is the revolutionary hydroponic feeding of dairy cows. On farms across the U.S., conventional pastures have been replaced by soil-less "grass factories" each of which grows a half ton of juicy forage a day. The grass factory is a shed 10 by 12 feet in which the controlled temperature, light, and humidity produce the optimum environment for the growth of grass in fertilized water.

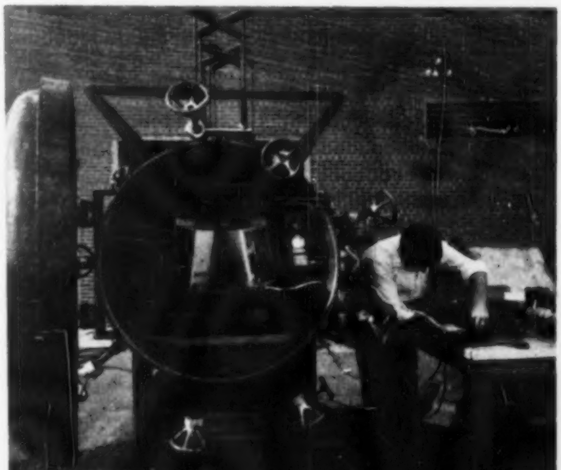
Other imaginative uses are the "atomic farms" in which medicinal plants are grown in carbon^{14}-dioxide atmospheres so that radioactive drugs can be extracted for use in tracer experiments, the development of a space cabin which recycles human waste for reuse, and research on algae farms that can thrive on human wastes while providing astronauts with food and oxygen.

This brings us back to Venus and the questions, "*Just what kind of an environment must a missile part live through?*" and "*How do you duplicate it on earth?*"

Habitat of a missile

The answers to the first question come from two major sources. First are the equipment-bearing rockets, large and small, that have blasted upward from launching sites in Germany, Russia, and the U.S. and the scientific satellites shot into orbit around our world. The other source is the astronomers who through telescopic studies and theory have computed the environs of the upper atmosphere, outer space, and on distant planets (more of this later).

For the answer to the second question, let's take a rocket trip. Let's see first the various environments in which missile components must survive for a



Outside the explosion chamber shown on title page, valves control expanding gasses in event of an explosion. The chamber, at Inland, tests electronic assemblies under various fuel-air atmospheres encountered in space travel.

cabinet than to go there.

Hudson Bay Co. president Alexander I. Newman has been associated with laboratory work since 1926, and his company is one of the pioneers in environmental space testing. Newman's engineer-executive background includes a BS in mechanical engineering and graduate study in business management. He is a member of the Environmental Equipment Institute, American Society of Testing Materials, and the Scientific Apparatus Makers Association.

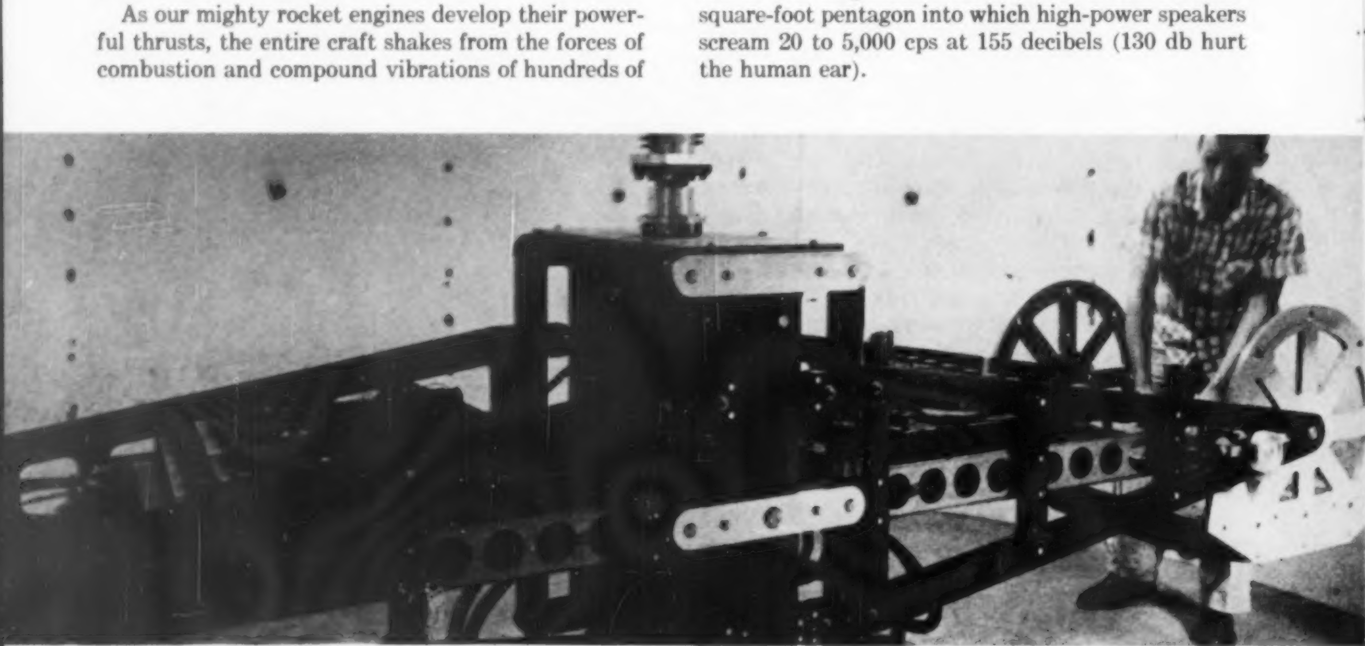
successful mission. And as we do, let's see how closely these conditions can be duplicated on earth. (We'll ignore the missile aerodynamics since this would have been tested in wind tunnels.)

When the blockhouse quarterback comes to the end of his 5-4-3-2-1 count-down, our space vehicle blasts off to the unknown. In an ICBM, this acceleration reaches 60*g* (a *g* being equal to the force of gravity on earth). The shock of blast-off can warp frameworks and force open fasteners, brush contacts, and tube filaments. Giant centrifuges, can subject two tons of equipment to 100*g*; smaller but faster centrifuges, can produce 250*g* with 100-pound loads. Rocket sleds at Edwards Air Force Base, Calif. can achieve 600*g* for fractions of a second.

As our mighty rocket engines develop their powerful thrusts, the entire craft shakes from the forces of combustion and compound vibrations of hundreds of whirling parts. Vibrations can cause electrical contacts to open and materials under stress to fail. Mechanical shake tables, which resemble loudspeakers in principle, subject samples under laboratory conditions to a range of pure vibrations or random vibrations from 0 to 5,000 cps.

Sound as a mechanical force

Acoustic noise is a mechanical force newly recognized as being even more destructive than vibration. Sound acts directly on all parts of a component, while vibration is applied only to the mounting point. The loud roar of our rocket engines, their many internal reverberations and overtones, can cause vibration-type failures not detected by vibration testing. An outstanding acoustical chamber is Avco's 10.5-square-foot pentagon into which high-power speakers scream 20 to 5,000 cps at 155 decibels (130 db hurt the human ear).



Whirling accelerometer at Inland can test 600 lbs. of space equipment at near fantastic velocities—up to 100 Gs. Sequence to the right shows components mounted on accelerometer table, accelerometer as the test begins, and at full speed. An auxiliary slip-ring assembly has been added to increase length of the table, and therefore the velocity. Encased in a roundhouse for protection (upper right), the machine is operated by two technicians.

Robert J. Dennis, chief liaison engineer of Cook Electric's Inland Testing Labs has worked there in environmental testing since 1953. Before that he did research at Argonne National Laboratory, controlled quality at The Hallicrafters Co., and maintained Navy shipboard electronic equipment. Dennis holds a degree in electrical engineering and memberships in the Institute of Environmental Sciences and Institute of Radio Engineers.

In the heart of our rocket engines are the fireboxes where oxygen and fuel meet in fiery embraces of 4000 F. While the metal walls of the combustion chamber are cooled by liquid oxygen rushing into the firebox, apparatus close to the rocket engines, such as hydraulic systems, may have to operate in 1000 F heat. Large test chambers can reach 1,400F (aluminum melts at 1220F) with the help of radiant heating strips.

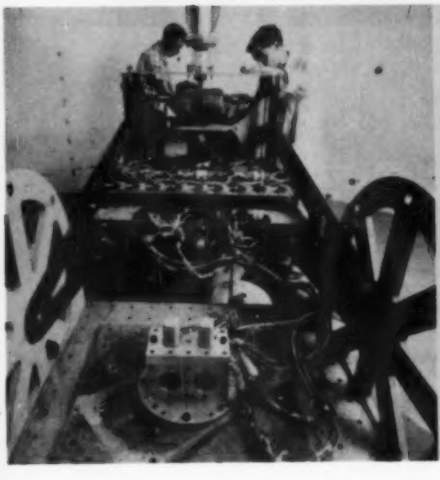
At these temperatures metals lose their strength, insulations weaken, semiconductors and lubricants fail, dimensions change, bearings freeze, and finishes are destroyed. Farther from the engines, electronic parts, tightly crammed together, generate their own heat. Above 200 F, nylon melts and capacitors can burst apart from the force of gases generated within by impregnant impurities.

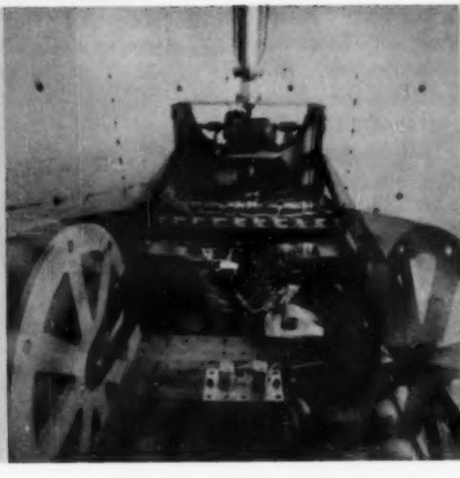
Temperature-wise, our entire missile must travel from the 90-plus heat of the Florida base to the –110 F cold at the top of the atmosphere to the –460 F absolute zero of outer space. Commercial environmental cabinets, such as are made by Labline Inc. and the Nucledyne Division of Cook Electric Co., can achieve a temperature drop to –120 F in less than five minutes with liquid carbon dioxide sprays, while liquid hydrogen can produce temperatures a fraction of a degree above absolute zero.

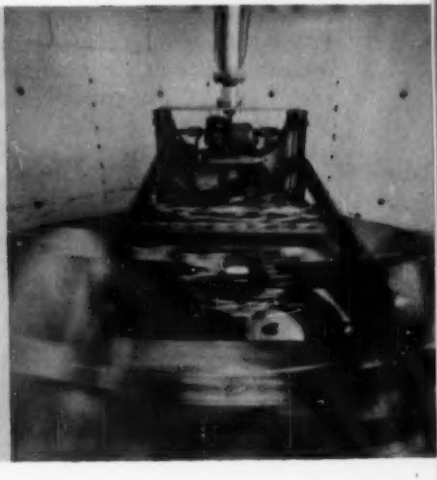
Coupled with the wide changes in temperatures is humidity. High humidity can cause electrical shorts, ice accumulations, dimensional changes, reduction of insulation resistance, and deterioration of unprotected surfaces. Humidity ranges from zero to 100% are duplicated routinely at all temperatures in environmental chambers.

We're now beyond the atmosphere. Our rocket's third stage fires and we're on our way to Venus.

Photographed by Jon Pownall







Beyond escape velocity

Once we have achieved our escape velocity of near-25,000 mph, there no longer is any acceleration. As we get farther and farther from the earth, its gravitational pull becomes weaker and weaker. Finally, we experience weightlessness—absence of gravity—the sole environment that cannot be duplicated on the ground. (Aircraft on elliptical climb-dives achieve weightlessness for only 40-second periods.) Lack of gravity is a small consideration for designers. The only requirement is that equipment not rely on gravity, as a relay might on ground installations. Weightlessness, however, is a psychological barrier that space travelers must push aside.

In the clear black of outer space, there is no external heat except from sunlight. Satellite experiments have shown that the internal temperatures of closed space capsules can be moderated successfully by using special skin coatings or by applying alternating dark and light paint strips, the dark to absorb heat, the light to reflect it. In airless space, with nothing to attenuate it, sunlight is many times stronger than at the equator on earth. Tests with lamps that duplicate the sunlight color spectrum and deliver 120 watts per square foot are used in performance tests of semiconductors, which are quite photo-sensitive.

With the rockets' fuel spent, there is virtually no vibration or noise. The rest of the space environment consists of a complete vacuum, micrometeorites, and nuclear radiation. In environmental laboratories, the vacuum at 200 miles above earth can be duplicated. The long-range effects of dust and sand-sized micrometeorites can be compressed into a few hours in sand-blast chambers that blow up dense sand storms of 30 mph.

The effect of cosmic rays also can be duplicated on earth. The impacts of these high speed particles on the missile skin send showers of gamma and x-rays into the interior. Such radiation can be deadly both to man and materials. Studies at Inland with a high intensity cobalt-60 source in the nuclear airplane program, for instance, showed that this radiation degrades rubber and lubricants and can cause plastics literally to fall apart. Nuclear radiation also destroys the electronic properties of semiconductors, transistors, and diodes.

What about our rocket to Venus? Can we duplicate the environs of other planets?

From arctic rooms to Mars rooms

Many environmental laboratories have test chambers labelled "The Tropical Room" or "The Arctic Room," indicating that here such components as automobile ignition systems can be tested in tropical or polar environments. It won't be very long, we feel, before Mars Rooms or Venus Rooms will be built simulating the complete environment of another planet. Fantastic? Let's see, keeping our knowledge of environmental limits in mind:

Moon—virtually no atmosphere, except for traces of argon; constant cosmic-ray and micrometerorite bombardment; vast changes in temperature, from +214 F in the sun to–243 F in the dark. Except for the light lunar gravity, which is less than a fifth of ours, this is easy.

Pluto—essentially the same as on the moon, except that its gravity is close to ours while its surface temperature is about –348 F—again a possibility.

Venus—same gravitational pull as earth's; atmosphere of carbon dioxide with clouds of formaldahyde or carbon suboxide mist; temperatures of from –9 F to +140 F. This, too, is easy for the environmental engineer.

Mercury—closest planet to the sun, resembles our moon in that it has no atmosphere and rotates so as to show the sun its same face; gravitational pull one-

Outside Inland's cobalt-60 gamma irradiation hotcell, an engineer operates slave manipulators (far left), which can be seen inside the cell at left. A 60-foot well in the room contains the largest-known source of cobalt-60. Components and devices are exposed to the source to test radiation effects on reliability. Hanging from the large hook, a monitoring device gives radiation-level readings. When the cobalt is uncovered, a purple glow emanates. Cobalt-60 leaves no radioactivity after its removal. Chickens also are being irradiated with cobalt-60 to learn its biological effects.

third ours; temperatures range from 770 F on the sunny side to absolute zero on the shady side. Again, no problem.

Mars—atmosphere is composed largely of carbon dioxide, with traces of water vapor, nitrogen, and argon. Its level surface is mainly red rock and sand covered at the poles by snow, and at spots in between by what may be plant life. Except for the low gravity, this is all duplicatable. In fact, Illinois Institute of Technology scientists are growing lichens and mosses in simulated Martian atmospheres and temperatures.

Jupiter, Saturn, Uranus, and Neptune — while they vary in size and degree, all have gravitational pulls similar or greater than the earth's; atmospheres of the light gases hydrogen, methane, ammonia, and temperatures from −200 F down. That any has a solid terrain, however, is doubtful.

And so, all of the various environs of the solar system—except reduced gravity—are within our grasp here on earth. Putting these components together is another story.

Environs are combined routinely in tests, but no single chamber has been built to combine all of the environs that even a small missile experiences in flights to the upper atmosphere and back.

Combining environs

The advantage of testing in a single environ is that the effect of this temperature or that vibration can be pinpointed. But in real situations, environs either can multiply one another's destructive capacity or, indeed, counterbalance them. Take a hermetically sealed capacitor.

If we heat it from 50 F to 170 F in 95% humidity while vibrating it at 55 cps, the seal may craze or develop small cracks through which the water vapor can penetrate to ruin the capacitor.

On the other hand, consider plastics. High temperature can cause a polymer to break up into free radicals, while nuclear radiation can cause the same polymer to cross-link and form larger molecules. Here temperature and radiation counterbalance each other.

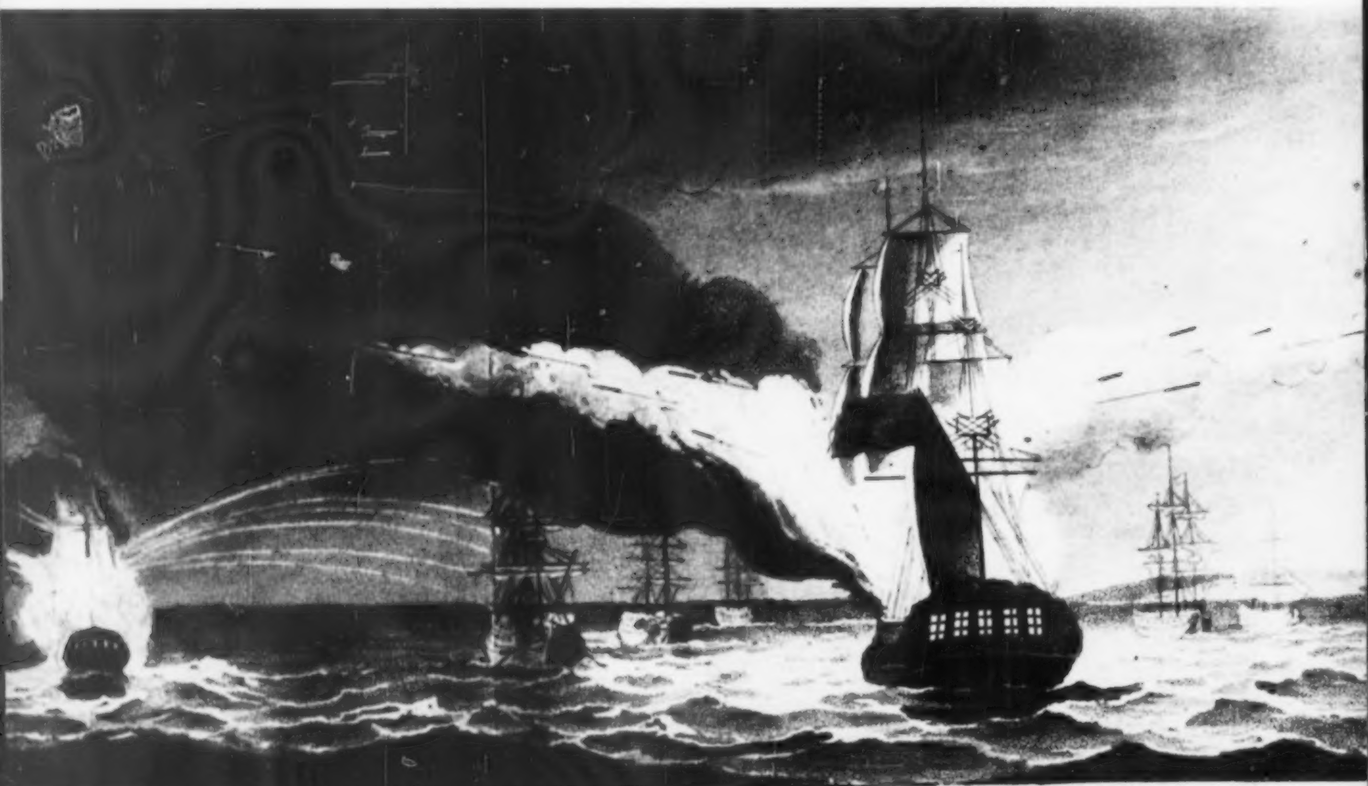
Today's tendency is toward tests in combined environments. The advantage is the lowered cost of testing as well as real-life circumstances. But the trend is slow. Temperature-altitude tests are as common as temperature-humidity tests. Temperature-altitude-humidity tests are less common. Even more rare are temperature-altitude-humidity-vibration tests. As one adds environs, the chances that the test is used decreases geometrically. Yet in actual operation, parts fail under *total* environments, as a result of various environs occurring simultaneously or in special sequences, like the rocket flight example.

To meet the challenge thrown to industry by national defense needs we must duplicate exactly the mission profile. We must place a component in a total environment chamber and program the conditions under which it must survive—from production line to launching pad, from blast off to Venus and back. The capabilities are at hand. All that is lacking is the facility in being.

The engineering and cost problems admittedly are enormous. (Wright Air Development Center estimates that a universal environment chamber would cost from \$5- to \$9-million.) But so is the need. Think of what the Wright brothers might have accomplished with a wind tunnel. ■

Hydraulic flow-stand tests an aircraft-oil thermostat assembly. Such tests in a single environ yield a precise reaction to one condition. A truer test would result from a combination of environs—since one condition can multiply or counterbalance the effects of another.

the rocket: a past and future history



Early rocketry techniques of the Greeks and Chinese were enhanced greatly by William Congreve's addition of reliable hardware. Congreve made the rocket a formidable offensive weapon by solving the engineering details of accuracy. His improved rockets were fired on American ships with unexpected success from British clippers in the War of 1812. Such scenes, described later by Francis Scott Key, anticipated those viewed by Americans 130 years later in the South Pacific during WW II.

Editor's note: Rocketry today is history in the making, and it's a safe bet that history books of the 21st Century will consist of as much science as politics—reversing a 4,000-year-old trend. What will these histories say about man's rocket to space? Listen…

by **Dr. Meyer M. Markowitz,** *thermodynamic and physical chemistry group leader, and* **Norman P. Gentieu,** *technical writer, Foote Mineral Co.*

Forty years ago, in about 1960, a survey of rocketry would have been merely a pleasant diversion. Now, on the threshold of the 21st century, however, the picture is different.

The art of rocketry has increased in complexity. Its hardware has evolved from a random collection of crude gadgets to the intricate interplanetary machines now swarming in so-called outer space. Albeit, the story of rocketry should be documented adequately before salient data disappear into the maw of oblivion.

The history of the rocket is the story of an amazing development fostered by many talents and not a few geniuses—empiric and theoretical, scientific and literary. My account cannot document this technology in the elegant detail it so richly deserves. Rather, it will skim the peaks, paying particular attention to those contributors who best served the extraordinary evolution of the rocket.

Primitive random shots

In the year 160 A. D., the Greek satirist Lucian wrote what is probably the first interplanetary romance. Entitled *True History*, for reasons known only by the author, it describes a flight to the Moon. However, this fiction was antedated by two inventions. One was the legendary flying pigeon of Archytas, a wooden bird held captive on a string and put

Dr. Meyer M. Markowitz, as group leader of the thermodynamic and physical chemistry group at Foote Mineral Co., currently is studying the applications of lithium and lithium chemicals as propellant components. His interest in rocketry stems from participation in several government-sponsored rocket research projects at the research division of New York University. Since receiving his PhD from Cornell University in 1953, Markowitz has worked in the areas of physical measurements, propellant and high-temperature chemistry, and inorganic synthesis Active in several professional and honorary societies, he has published more than 30 articles for the American Chemical Society magazines and elsewhere.

in flight by a jet of either steam or compressed air. Toy or experimental model? The record is blank.

The other invention was a reaction engine called the aeolipile. It was built about the second century B. C. by a Greek scientist. It consisted of a revolving hollow sphere into which steam was introduced from a boiler underneath. Two bent tubes on opposite sides of the sphere served as outlets for the steam, providing the reaction necessary for motion.

The first European author to mention rockets may have been Marcus Graecus. In his *Book of Fires for Burning Up the Enemy* (written probably in the eighth century), he described what must seem to the present audience an incredibly primitive rig. The gist of his rocketry technique was this—if a compound of niter, sulfur, and charcoal were rammed tightly into a long narrow tube and set afire, the tube would fly through the air. Clearly an example of the bliss of simplicity wedded to the charm of enthusiasm!

Its most interesting aspect is the allusion to the propellant. Like all the old style rockets, the model developed by Graecus used a solid propellant—the potent if erratic concoction known as black powder—discovered by the Chinese in the Tang dynasty.

Tacticians soon recognized the desirable military attributes of the rocket. A Chinese chronicle, circa 1232 A.D., relates a siege of Kai-Fung-Fu, a city in southern China, by the Mongol Ogdai and his minions. In a move that must have nonplussed the attacking hordes, the defenders made use of rockets for the first time in actual warfare.

'Souped up' arrows

These models were ordinary arrows "souped-up" for the occasion by an attached tube, open at one end and filled with a generous portion of black powder. The overall effect did not differ markedly from the type of skyrocket used later in nocturnal patriotic celebrations. The "arrows of flying fire," created a terrifying diversion. Unfortunately the psychological shock did not endure and Kai-Fung-Fu ultimately was captured.

Spectacular devices like the Chinese fire arrows, of course would not remain in obscurity. In a comparatively short time, Marco Polo and other early explorers were describing these wonders of Oriental ingenuity to European and Near-Eastern readers. Enterprising amateurs readily responded to the delights of the new art. As early as the 14th century the Arabs were conversant with the mixing of powder and manufacture of rockets. These hazardous skills were introduced into Europe about 1400.

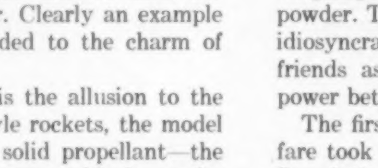
Field tests were made in Berlin as early as 1688 with 50 and 120-pound rockets carrying a bomb weighing 16 pounds. The propellant was still black powder. The black powder grain with its destructive idiosyncrasies must have maimed and killed as many friends as foes, and thus preserved a balance of power between the opposing teams.

The first large-scale use of rockets in actual warfare took place in India shortly after the American Revolution had been brought to its successful culmination without the services of this ordnance species. A wealthy prince of Mysore, Hyder Ali, bamboozled and buffaloed the British in a series of battles from 1780 to 1799.

According to available literature, the Mysore rockets weighed six to 12 pounds and consisted of an iron tube packed tightly with powder and guided by a long bamboo pole. (Hence, the bamboozling effect mentioned earlier.) These rockets had an effective range up to a mile and a half and inflicted both confusion and casualties.

'The soul of artillery without the body'

News of the novel "secret weapon" soon spread to



Congreve's successor, Hale, developed the rocket used in the Civil War. Powered by black powder—the original solid propellant—Hale's rocket attained stability of trajectory by means of curved vanes at the exhaust end.

Norman P. Gentieu's technical writing background probably violates every canon of this young but serious profession. After three years with the duPont Co., Gentieu played jazz piano, wrote and lectured on jazz, studied music composition, and performed library research for the Bibliographical Planning Commission. He spent four years as a Navy test supervisor, and published monthly essays for Navy's The Bulletin. *In 10 years as technical writer for a chemical company he wrote more than 100 articles for the trade and technical press. At Foote Mineral Co., Gentieu writes about ultra-purity metals, and publishes articles in* Foote Prints. *He is a senior member of the Society of Technical Writers and Editors.*

Europe, finding a special reception in England. General Desaguliers, the fire-master of the Royal Military Academy, tried his own hand at this exotic ordnance — unsuccessfully. His successor, Colonel (and later Sir) William Congreve initiated an experimental research program at the Royal Laboratory at Woolwich.

Convinced that rockets possessed immeasurably superior advantages over cannons and the other conventional artillery of the day, he succeeded in building rockets that helped dissuade Napoleon from his delusions of grandeur. Like the longbowmen of Henry V, Congreve's rocketeers sent their shafts crashing down on the heads of the French forces with devastating effect.

In American history, *The Star-Spangled Banner's* "the rocket's red glare, the bombs bursting in air" is an account by Francis Scott Key of the success of Congreve's favorite weapon in the War of 1812.

Although the British routed American troops at the Battle of Bladensburg, marched to Washington, and burned it to the ground, they shot their rockets in vain at Fort McHenry from their aptly named rocket ship Erebus.

Congreve's rocket program

William Congreve benefited in his rocket program from at least two influences: the practical achievements of his free-wheeling predecessors and an awareness of the theoretical aspects of rocket flight. Sir Isaac Newton's famous Third Law of Motion had stated that to every action there is an equal and opposite reaction, and Congreve realized that the foundation of rocket operation was the principle that motion is produced in a direction opposite to that of a rapidly moving fluid.

Although Sir William introduced no drastic innovations, he can be said to have contributed substantial improvements to a neglected branch of ordnance. He gave his rockets an enhanced hardware by forming them with iron cases instead of paper. He shortened the stabilizing tail stick and obtained a more reliable trajectory. He attained a higher density of packing in his rockets by soaking black powder in alchohol and thus eliminating voids.

Designed for gracious lifting

One period that might have seen a great recrudescence of the rocket art was that of the War of the Rebellion. For example, from 1861 to 1865, the Richmond Arsenal alone produced 3,985 rockets for the Confederacy. Experiments were made on new types of powder, shells, and rockets.

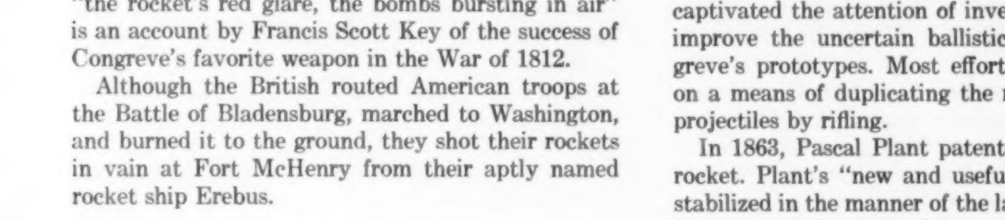
In both North and South, the rocketry concept captivated the attention of inventors who sought to improve the uncertain ballistic properties of Congreve's prototypes. Most efforts were concentrated on a means of duplicating the rotation imparted to projectiles by rifling.

In 1863, Pascal Plant patented an improved war rocket. Plant's "new and useful" *rocket-torpedo* was stabilized in the manner of the later-day *Honest John* by jets emerging from the case at right angles to its longitudinal axis.

Another Southern gentleman, the scholar and erstwhile business partner of Samuel Morse, Taliaferro Shaffner, introduced in 1869 an improvement that would make his rocket "more fatal" in battle by scattering metal. The head of Shaffner's rocket contained a priming charge, which on impact would burst a thin dividing wall and explode nitroglycerine in the body of the rocket.

Pioneers of outer space

Ultimately, it was the idea and the possibility of space travel that prompted renewed interest in rock-



America's rocket pioneer Dr. Robert Goddard fires first successful liquid-propellant rocket on March 16, 1926.
During WW I, Dr. Goddard became aware of the limitations of solid-fuel rockets.
In WW II his accomplishments were well-known in Germany, but he was ignored as impractical in the U.S.
Some results of Goddard's "impractical" experiments are the first faster-than-sound rocket, the first rocket in a vacuum, and the bazooka.

ets. Indeed, the recognition came at a comparatively early stage that the rocket as a self-contained power plant would be the only type of vehicle capable of exploration into the virtual vacuum of outer space. To the Classic Period of rocket development (the first half of the 20th century) belong the great pioneers who laid the foundations of the fecund, modern period: Konstantin Edvardovich Tsiolkovskii, Robert Hutchings Goddard, and Hermann Oberth.

Tsiolkovskii

Science frequently moves in mysterious ways, as happened with the great Russian theoretician, Konstantin Edvardovich Tsiolkovskii. Isolated, impecunious, even lacking a formal education, Tsiolkovskii formulated *a priori* the bases for rocket travel in outer space, completing his elaborate description in 1903 — the same year the Wright Brothers made their historic flight.

Tsiolkovskii's interest in the possibility of space travel was based on his own personal philosophy that the whole universe was the heritage of mankind. He taught mathematics and physics in a small Russian town for his livelihood, but his thoughts ranged far from his provincial surroundings.

His first major preoccupation was with the theory and construction of metal dirigibles, but eventually he turned to a study of flight into space with a reactive-engine rocket using liquid fuel.

Beset by an amazing lack of laboratory facilities and with a chronic shortage of funds, Tsiolkovskii rose above these limiting factors. He not only established the basic principles of space flight with a vehicle powered by liquid oxygen and hydrogen, but also conceived many ideas that are an integral part of today's long-range ballistic missiles and spaceships.

But even with this achievement to his credit, Tsiolkovskii remained dissatisfied. *"All my life consisted of meditation, calculations, and experimental work. . . . The main things are still ahead. Will there be enough strength and ability to transform these thoughts into reality?"*

The authors submit, as a fillip of encyclopedic knowledge, that Isander and Kondratyul, disciples of the great Russian scientist, mentioned lithium and boron as possible fuels for space travel many years before the desirable properties of these two elements were appreciated fully.

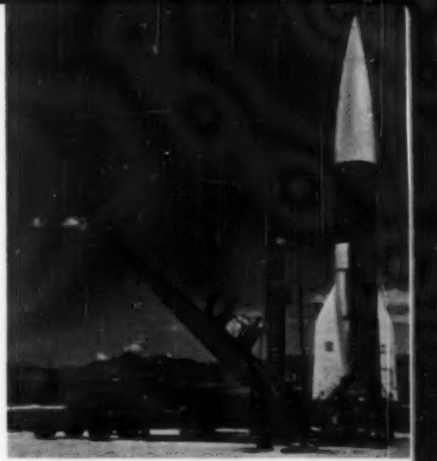
Goddard

Dr. Robert Hutching Goddard's accomplishments often have been recounted in detail. Perhaps not so well known are Goddard's diverse investigations. The essence of his work is contained in two publications originally sponsored by the Smithsonian Institution: *A Method for Reaching Extreme Altitudes* and *Liquid Propellant Rocket Development.*

Goddard's theoretical work was augmented by a series of successful practical experiments, and he put a liquid fueled rocket in flight for the first time in 1926.

It should be remembered that in previous rockets, black powder was the usual propellant. The actual development of the rocket as a vehicle with a precise path depended on the use of liquid propellants. Tsiolkovskii had realized this fact also, but Goodard's work confirmed the theory.

Not generally recognized are Goddard's studies that range over the entire field of rocketry. For example, between 1906 and 1910, Goddard had recorded notes on such subjects as: multiple rockets; liquid H, O, N_2O_4, and other materials for rocket propulsion; reaction by streams of ions to furnish rocket propulsion; use of solar energy; raising an explosively propelled apparatus to a great initial height by balloons; cameras sent around distant planets and returned to earth; circling a planet to decrease



"Once awe-inspiring but now primitive," Germany's V-2 rocket of WW II prepares for a test firing in 1946. When questioned about the V-2, captured German scientists replied, "Why don't you ask your own rocket pioneer Dr. Goddard? We learned these things from him." Hermann Oberth performed secret research on the V-2 prior to its development by Walter Dornberger for Hitler's huge crash program.

speed before landing; and production of hydrogen and oxygen on the moon.

Goddard's achievements are so notable that it is difficult to understand why he remained in obscurity during his lifetime (he died in 1945, bypassed by the U.S. military as being too "impractical").

When Americans were questioning captured German scientists after WWII about the *V-2* program, the Germans replied: *"Why do you ask us these questions? Why don't you ask your own rocket pioneer, Dr. Goddard? We learned these things from him."*

Goddard was the first investigator to shoot a rocket faster than the speed of sound and he was the first to prove by actual experiment that a rocket will work in a vacuum. This had been an academic bone of contention for centuries, but until Goddard ran his test no one actually knew.

Another Goddard "first" was the bazooka, the basic idea of which he had developed as early as 1918.

Oberth

In 1923, a small pamphlet was published that led to the formation four years later of the German Rocket Society and exercised an influence all out of proportion to its size.

The slender book was Hermann Oberth's *Die Rakete zu den Planetenräumen*. It was actually a highly theoretical description, bolstered by the necessary formulas, of Oberth's entire concept of rocket development using liquid fuels, the transportation of human passengers, and other subjects fundamental to modern rocket technology.

Previously, in 1917, Oberth had submitted a project for a long-range missile with alcohol containing water and liquid air as propellants. However, at that early date and in the 1920s, his suggestions also were shunted aside as impractical.

One of the difficulties lay in convincing his colleagues that any kind of a reaction would be effective at extreme altitudes. They, of course, remembered the adage that "nature abhors a vacuum," and, reasoning by false analogy, had equated nature with rockets.

Later, Oberth did some secret research work preliminary to the development of the *V-2* and engaged in many other rocket-oriented activities. In the United States he served in a consulting capacity on secret projects at Redstone Arsenal.

However, his chief claim to fame was his rigorous and correct solution of the basic problems of interplanetary flight and the many sound suggestions for implementing such flights.

Naturally there are many other pioneers who helped usher in the Era of Space Technology. To Robert Esnault-Pelterie, Jules Verne, Fritz von Opel, Willie Ley, I. M. Levitt, and a host of other savants and science writers, we owe a debt of gratitude.

The early Space Age

A suitable preface to discussion of the Space Age birth is the cherished cliche that necessity is the mother of invention. (The matter of paternity never has been clarified satisfactorily.) I refer specifically to the crash program that inspired devotees of the rocket in Germany set up in the closing years of World War II.

Originally this activity was a function of the German Rocket Society which attempted to perfect the rocket during the 1920s and '30s—first as a means of space travel and then under the auspices of the German army as a "new" war weapon.

It is now well known in retrospect that German accomplishments in rocketry during World War II were considerable. The effort expended at Peenemünde, the German Rocket Development Center, did bring results, as many harassed citizens of London could testify.

Among the rocket-derived devices evolved are the

Only the foresight of such rocket pioneers as Tsiolkovskii, Goddard, and Obert could have made the thought of interplanetary colinization serious. This permanent lunar colony is contained in the pressurized dome, 90% underground. Finger-like hydroponic farms extend from the dome. Hydrogen-powered rockets are equipped with blunt ablating tail cones for safe tail-first re-entry into earth's atmosphere.

The rocket's history is an amazing success story, which in this article stretches over 2,200 years. After sporadic investigations in Greece, China, Berlin, and India, the rocket was improved substantially by William Congreve and used to strengthen the already-powerful British Navy (first photo). The rocket's "Renaissance" in the mid-20th Century resulted from a desire for space travel. Extensive research and development was given to satellites, spaceships, and rockets (such as the Honest John, center photo). The half-century following the rocket's Renaissance brought tremendous advances. By the 21st Century, rockets (photo far-right) make regular interplanetary explorations. Designed to fly both as a space rocket and as a ramjet airplane, the vehicle is shown approaching the Martian outer moon "Deimos." It is propelled by atomic heat, reacting with either hydrogen or water. Inside an atmosphere, heat expands the air to power its ramjets.

V-1 buzz bomb and launching catapult, the once awe-inspiring but now primitive *V-2*, rocket-propelled depth charges, deceleration rockets for laying sea mines, liquid rocket aircraft take-off assist units, and various guided missiles.

Never put into general operational service, but in advanced stages of development, were the jet fighter and the Walter closed-cycle submarines. The former owes its practical realization to the excellent work of Sir Frank Whittle in the 1930s. The latter, though not operating on the rocket principle, was made possible by experience gained in handling high concentration hydrogen peroxide in the rocket program.

A digression on fuels

Since energy is the open secret of the rocket's success, it is eminently apropos to make a cursory reference to the problem of rocket propellants. For years bitter controversies raged in military and civilian circles on the relative merits of liquid versus solid propellants. The liquid types at first seemed to be in the ascendancy, especially the highly touted hydrogen-fluorine system. Unfortunately, engineers never were able to overcome the inherent difficulty of hydrogen's low density even in a liquid form, which necessitated an unseemly volume for its container.

In the early 1960s, two staunch contenders for solid honors, ammonium and lithium perchlorate, became available in large commercial quantities. Their high oxygen content (over 60% for lithium perchlorate and in a compact, stable form), and the unique ability of the lithium compound to enhance the stability of other propellants led to a general adoption of solid perchlorate systems in chemically fueled engines.

At one time, it seemed that chemical propulsion engines were doomed to absolute obsolescence, with the rapid and successful development of nuclear and ion power plants for space vehicles. However, experience has proved that chemical power is suited ideally for getting our space shuttles up through the first 100 miles of the earth's cloying atmosphere. At this level, we of course transfer via the low-level space stations to the interplanetary expresses which are now powered by either atomic engines, ionic propulsion systems, or even the more recent solar power plants, depending on specified flight speed.

The crux of this situation is merely that after the spaceship breaks through the atmospheric blanket, energy requirements are much lower and in outer space the non-chemical energizers with their ultra-high velocities can perform *in vacuo* and at their highest efficiency.

The most important contribution in this category has been the adaptation of a nuclear power system to the peculiar requirements of the rocket. Not only did the engine have to be designed to somewhat ungainly specifications, but the temperatures and stresses imposed on the rocket's structural materials were horrendous.

As usual, much of the pertinent information is classified but I can reveal that the propellant finally selected consists of hydrogen molecules dissociated by an atomic pile into hydrogen atoms. The essential radiation shield is a thin amorphous skin of lithium hydride, and the shell is mainly of a newly developed ablatent armor plate.

The middle Space Age

At mid-century — October 1957 to be exact — the unexpected and unprecedented launching of the formidable Russian sputniks lent great impetus and stimulation to rocket research and development in the United States. At last the Americans realized that the rocket was here to stay.

In fact, it became quickly and soberingly clear

that the rocket was the only power plant capable of use on their intercontinental ballistic missiles (the *Atlas*, the *Titan*, and later the *Nova*) because of its independence of outside environment and its very high horsepower output per unit weight of rocket.

After a dallying program in the 1945-55 era, the United States began a desperate race to regain lost prestige as well as bargaining power at international conference tables. The Americans were able to augment their scientific ranks by manpower from the huge reservoir of skills and talents associated with the pin-ball, juke box, and allied electronic industries.

The main currents in rocket development have brought us to such a peak of perfection in this year 2000 that we again are becoming complacent.

Even today there is still something tremendously exciting to me in regular rocket express to Mars and Venus with exploratory trips (or space probes as they are known in the trade) to Jupiter, Saturn, and Neptune contemplated in the near future. And consider the burgeoning industry in ultra-pure materials made possible by trouble-free operation of factories in the uncontaminated atmosphere of the moon.

Actually, the probing of space followed the rather clear-cut pattern formulated in 1959 by the National Aeronautics and Space Administration. What deviations occurred could be attributed to the unpredictable sensational stunts of the Russians who, it seemed to casual observers, always tried to surpass the United States in comparable programs.

1960 to the present

A resumé of rocketry development in the past four decades only can touch the main items. By mid-1959, 15 rockets had been lofted to orbit with varying degrees of success and life expectancies ranging from a few hours to infinity.

These early models included three *Sputniks*, three *Explorers*, two *Vanguards*, three *Pioneers*, two *Discoverers*, *Project Score* — the articulate *Atlas* (which established a Republican priority — "the first fireside chat from outer space"), and *Mechta* — the Russian dream of unlimited Lebensraum.

In America, the evolution of the rocket progressed in startling leaps and bounds. Beginning with the *Thor-Delta* of early 1960 (with a 150,000-pound thrust), astronautic scientists had produced *Atlas-Centaur* by the end of 1961. This model featured the world's first liquid hydrogen-oxygen engine and developed a potent thrust of 390,000 pounds.

However, this was soon dwarfed by the huge *Saturn*, powered by a cluster of eight engines with a total thrust of 1½ million pounds. In the 1960s, *Saturn* placed three communications satellites into 24-hour orbits 22,300 miles above the equator. These vantage points gave the United States a triple reflector to beam radio and TV messages to all points on the earth.

By 1970, *Saturn* was surpassed by *Nova*, the climax of the chemical propellant rockets. *Nova* generated the unheard-of thrust of 6 million pounds! This finally was deemed the optimum push for shuttles from Earth to space stations.

After years of planning and preparation, the United States finally landed two explorers on the moon in 1969 and by '75 had sent expeditionary forces to Mars and Venus. Having no men on the moon, the Russians sought to offset their defeat by beating us to the red planet and indeed did place a melancholy Slav on sparse, frozen vegetation a few days before our own spaceship landed.

'Mrs. Vee'—darling of the '90s

In the 1990s, a more modest but extremely important phase of the overall space program was eventuated. This was what scientists called the

Maneuverable Recoverable Space Vehicle and what the lay press referred to as "*Mrs. Vee.*"

MRS-V performed a number of essential functions — it serviced manned space stations, observatories, space depots, and other items in the galaxy of satellites in orbit around the earth; it made possible the regular correcting of orbit discrepancies; and, most vital, it proved to be a key factor in maintaining "open skies" inspection, thus enforcing modern Checkmate Control.

Checkmate Control, of course, is the concept of holding a possible total war in abeyance by means of an uneasy equilibrium. Simplicity itself, it consists of keeping the well-known balance of registered ordnance satellites in the skies at all times.

Traffic, the old bugaboo of earthbound vehicles, has become a major problem of the Space Age. Fortunately, relief is in sight. A new type of traffic control soon will be introduced. It is based on the four coordinates of non-Cartesian solid analytical geometry plus an automatic electronic adjustment of relative sidereal time.

This is only one of many problems that have been concomitants of the new day of travel. In a few decades, the Space Age has introduced the most profound changes in the entire scheme of living. For example:

1. *The economy of nations is now based on the astronautics industry, instead of on war.*

2. *The necessarily complex decisions that implement the future are made by programming the best conclusions of a select group of experts and submitting this "feed material" to a bank of electronic and nuclear computers.*

Our future in space

As we verge on still another age of space conquest, we may be impatient that our more recent progress has appeared more static than dynamic. Yet, on reflection, consolidation of the tremendous advances made in the last 40 years seems a truly gargantuan task.

For example, only now are our scientists developing satisfactory shields against the lethal Van Allen radiation belts. And the Probability of Fully Accomplished Flight (the PFAF factor) is still too low in the opinion of many reputable astronauts. And there are still other major problems to be worked out, chief among them the philosophical.

How can we justify — even in the growing complacency of the 21st century — the expensive, elaborate, and exaggerated preoccupation with non-terrestrial matters? Is it worthwhile to push out even farther into space? No better answer exists than that given to his 20th century critics by the brilliant Prof. Theodore W. Richards, who taught analytical chemistry at Harvard University from 1889 to 1929:

"*. . . why should one spend several years trying to master the determination of the electromotive force of a cell prepared of almost impossibly pure materials, or seek to compare the compressibilities of substances under pressures which are quite beyond the range of ordinary experience?*

"*How will this remote philosophical knowledge yield any practical use? Who can tell? Faraday had no conception of the electric locomotive or the power-plants of Niagara when he performed those crucial experiments with magnets and wires that laid the basis for the modern dynamo. When mankind discovers the fundamental laws underlying any set of phenomena, these phenomena come in much larger measure than before under his control and are applicable for his service.*

"*Until we understand the laws, all depends upon chance. Hence, merely from the practical viewpoint of humanity's progress, the exact understanding of nature is of the most important of all problems presented to man.*" ■

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can research save the railroads?

by an Industrial Research staff reporter

A CENTURY OF GROWTH has seen America's railroad industry develop from a prodigious infant into an awkward adult, tied to the apron strings of outdated legislation, powerful organized labor, and forced inefficient operations in the face of strong competition.

For more than 50 years, a near-monopoly in transportation carried the railroads into a great surge of prosperity. During the years of expansion which carried through the first quarter of this century the railroads did not have to worry about efficient operation, modernization of equipment, or competition from other means of transportation.

Today the situation is reversed. The expansion of an intricate highway network through an integrated state and federal system, coupled with government-built airports at every major city and many smaller ones, has enabled the railroads' competitors to capture a good portion of the freight business and threatens extinction of rail passenger service as we know it today.

Today, only 6% of inter-city travel is made by rail while 84% goes to the auto. Airlines carry 4%, buses 3%, and 3% to miscellaneous combinations. Thus a return to the rails of only 10% of the auto traffic would mean doubling the present rail passenger business — a goal which some railroad men believe can be achieved through more efficient use of equipment and materials: research.

Certainly research can save the railroads many millions of dollars, but is it powerful enough to save the railroads?

The research payoff

Enormous research and testing expenditures have paid off in terms of competitive operation: a higher energy-to-fuel ratio (diesels over steam engines); longer equipment utilization (manganese-steel switch points, continuous rails, etc.); and new innovations (punch-card systems to classify cars in less time, or the "piggyback" truck-flatcar combination). Yet the rail industry still wobbles on the track of economic disaster. Why?

Imagine a mile-long train of featherweight *two-wheeled* cars snaking along curves at 200 miles an hour. Such a research dream has been approached in an actual Chicago-to-Detroit experimental run by the Chesapeake & Ohio Railroad. The train goes back to a principle used on roller coasters since 1880. A single axle and single pair of wheels are located at the rear; the front part of the car, wheelless, is coupled to the car ahead, supported by its rear wheels. The integration is

like the vertebrae of a snake.

Not too long ago, a million dollars worth of research convinced the late C&O board chairman and New York Central president Robert R. Young that radical departures like the dream train are not only practical but imperative. His "train X" could be manufactured cheaply enough so that three of the new steel and aluminum alloy coaches will cost only as much as one ponderous, 55-ton conventional coach, and its running costs could be cut in two.

(Train X was tried and discontinued because it was deemed too light, *perhaps one of the reasons that led to Young's subsequent suicide. The Rock Island* Rocket *now is experimenting with a similar train on the Chicago-Peoria run.)*

But despite which of recently proposed dream trains makes the grade, the point here is to consider how such a train would be manned, regulated, and financed on a wide scale. Would the union insist on idle oilers for the nonexistent wheels? Firemen to shovel yesterday's persisting dream-pile of coal, obsoleted now by 15 years?

Would the Interstate Commerce Commission cut the length of the train, transforming it from its efficient snake into several shorter, costlier units? And how would management, crushed by regulatory powers on top and unions below, feel about financing the venture?

The bed of feathers

Management considers featherbedding to be the industry's biggest burden. Union leaders argue that railroad wages are less than those in other heavy industries. Management counters that when wages are based on a straight time value, the railroadman has a big edge.

In 1919 on the old steam locomotives, 100 miles was considered a day's work for railmen. Today, with rapid diesels, the 50-year-old rule still holds, and some rail workers receive a full day's pay for just a few hours' work. Another antiquated law guarantees that even if the railman works for *one* hour, without traveling 100 miles, he gets a full day's pay.

One run, since discontinued, was the three-hour and 20-minute trip on the B&O from New York to Baltimore, which involved travel in two "divisions." The crew worked less than seven hours for the round-trip, laid over four hours—and drew a full *four* days' pay.

Yet, unions continue to press their demands on a sick industry. They want special allowances for such routine duties as inspecting rolling stock, coupling or uncoupling cars, and changing engines. They ask for costly fringe benefits, such as a month cumulative sick leave, extra vacation days for every year of service, even birthdays off!

In a desperate attempt to save their economic lives, some railroads turned to automation and other labor-saving methods. Automation was threatened with a walkout for the New York Central. The Seaboard Air Line RR successfully tested a completely tape-controlled trip, but has not put the method into use.

The labor problem not only continues, it increases. An extreme example perhaps, in more ways than one, but Thomas Goodfellow, president of the Long Island Railroad, tells of a crew member who received a law degree during his free time between commuter rush hours — and now practices law on the same schedule!

Regulation on top of regulation

The railroad delemma presented by idle labor and idle expensive equipment is great. Yet, the situation is many faceted. Alfred E. Perlman, who succeeded Young as president of the New York Central Railroad, ascribes the real problem to discriminatory taxes and other government abuses.

As early as 1916, investors recognized that government influence might keep railroad earnings low, and railway investments began to decrease. In 1916 the railroads asked Congress to reorganize the system of supervision. Many of the requests to change legislation considered obsolete 50 years ago still have not been granted.

The railroads not only have been hampered by the fact that, unlike other enterprises, they must live with strict federal regulation, they also have been severely damaged by many short-sighted and overly cautious decisions by their ultra-conservative foster mother—the Interstate Commerce Commission.

With complete rate-fixing power over the railroads, the ICC has striven for an unbiased position by encouraging competition and success of any and all transportation — despite the economic advantages of one over another.

Recently, in order to meet competition, railroad management asked to reduce the freight rate on tin. They pointed out that the existing rate was four or five times actual cost, but the ICC held that the existing rate was needed to allow other carriers to compete for the traffic in tin.

Similarly, in 1954 the railroads

ILLUSTRATED BY KAULFI

were refused a profitable rate on molasses. ICC chairman Anthony Arpa stated that price cuts "disturb existing manufacturing and shipping relationships" (as did Henry Ford's price cuts!).

By preventing the railroads from competing for traffic they could handle profitably, the ICC forces them to maintain higher rates on other traffic than they normally would.

Truck vs. rail

The truck industry, only slightly controlled by the ICC, has made rapid gains on railroad freight, despite the fact that railroad productivity (expressed in ton-mile per employe) is about five times truck productivity. If expressed in ton-mile per employe-*hour*, the difference would be even greater. Railroad costs, also, are less per ton-mile than truck costs.

Why, then, has the trucking industry made such amazing gains over rail?

Under early government regulations, railroad rates were based on *value* of service rather than *cost* of service. The more expensive item was charged higher shipping cost; heavy, bulk items had lower rates.

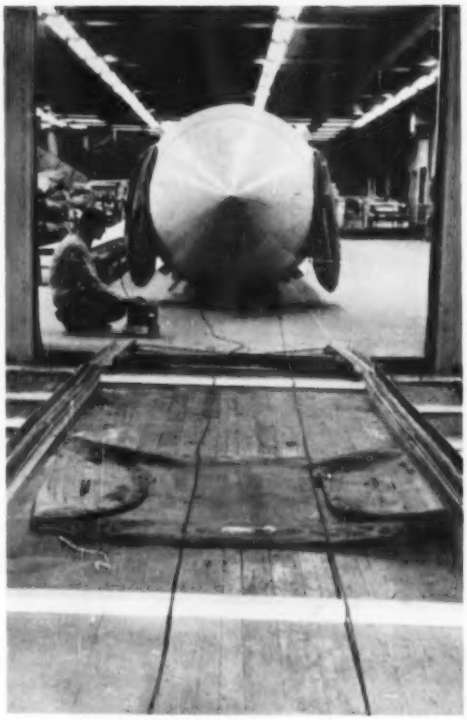
In the railroads' early, near-monopoly days, this basis seemed fair and workable. But with the inevitable arrival of competition the railroads were left completely helpless.

A few of the appeals to the ICC resulted in rate changes, but red tape involved in ICC decisions was so extensive it took the railroads approximately a year to get approval on just one rate change. And most appeals for revision of outdated rates were refused because the ICC wanted to preserve the old rail rate structure—thus allowing all carriers, despite their productivity, a "fair share" of traffic.

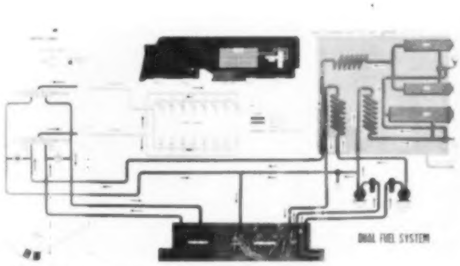
Yet the ICC has no power to prevent other freight carriers from reducing rates to compete with railroads.

Obsolete government policies affect not only the railroads, but also the nation's economy as a whole. Encouragement of all modes of carriers forces maintenance of more transportation than the nation needs. Outdated regulations impair efficiency and boost railroad prices and, in turn, consumer and industrial prices.

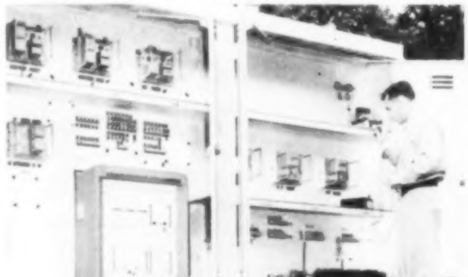
Despite recent attempts to reduce some ICC powers, the railroad industry is regulated as strongly as ever. Congress has been accused of pork-barreling with local air and water transportation, and government-built airports increase the railway problem.

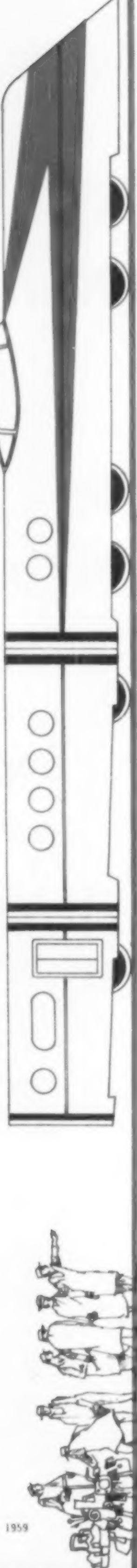


MISSILE BY RAIL *eliminates costly air freight, previously considered only safe method. Missiles now ride surrounded by cushions of air.*



DUAL FUEL SYSTEM *permits cheaper petroleum to be used in diesels. Below, Servo Corp.'s "Servosafe" hotbox detector, is a major advance.*





◀ **HOT ON THE TRACK** *of research, sketches show roads' advances from early steam engines through today's diesels and tomorrow's fantasies.*

The commuter stalemate

If the comparatively profitable freight transportation presents a problem, forced commuter service is a tragedy that swallows much of the meager freight profit. Labor and equipment for commuter trains lie idle between rush hours—but they still must be maintained. Expense reduction is impossible with present labor and government regulations.

An ICC examiner, Howard Hosmer, has predicted publicly that all railroad passenger service soon will be ended if rail travel continues to decline as it has in the last 10 years. He said that parlor and sleeping car service is likely to end by 1965 and coach service five years later. Commuter service would be the last to go.

Coupled with the burden of forced commuter service, the railroads face "municipal catering to competitors"—such as highway construction, fringe parking lots, and air and bus terminals. They must make unprofitable commuter runs and then pay a transportation tax on them; they are taxed highly for partly idle facilities; and they have no fare-fixing freedom to effect a recovery. Railroad management, on a policy level, does not exist.

The Illinois Central and Long Island Railroads did get a fare boost to alleviate the pressure, but most administrators believe that subsidy by benefiting towns is the only solution to the commuter problem.

Congress took a minor step in 1958, eliminating the excise taxes on freight and enlarging the power of the ICC over interstate fares. But it failed to drop the 10% excise tax on travel, which was imposed during the war to discourage travel. The main tax burden on the railroads is that imposed by state and local governments.

In spite of huge losses that railroads have suffered in passenger train operation over the past 10 years, many roads are fighting valiantly to make passenger operation profitable. Others have gone out of the passenger business entirely.

Research has tried to solve the problem with monorails—ideally suited for passenger service. Unfortunately, the capital investment involved has proved prohibitive for widespread use.

Although unable to solve the passenger problem, research certainly has lessened the economic burden. Centralized Traffic Control installations have resulted in tremendous savings in track maintenance, according to researcher Harry M. Sutcliffe of the Association of American Railroads (AAR).

The installations utilize electronics to allow a single dispatcher to control the movement of all trains traveling over as much as 500 miles of track, knowing the position of each train at all times. Great flexibility of operations has resulted, enabling the dispatcher to utilize time gained by one train. One track often can do the work of two, and proper scheduling of traffic increases efficiency by eliminating bottlenecks.

Today's payoff from yesterday's research

Research benefits are not new to the railroads. Today, the industry saves millions of dollars yearly from R&D performed in the railroad's infancy. The 50-year-old development of zinc and creosote treatments of ties, for instance, still saves the railroad $400 million a year.

Another early development was the control-cooled heat-treatment to eliminate transverse fissures in rails which were causing many derailments every year. It involved a $670,000 research investment, but has resulted so far in a total saving of $94 million. The 11-year study was initiated in 1931 by the engineering division of the AAR, through the American Railway Engineering Association.

An added benefit derived from this study was the information obtained on rail-end hardening. It was found that proper end hardening of the rails would save at least on building up of battered rail ends and prolong joint bar life a third to save the railroads more than half a million dollars a year.

Research also led to modern ultrasonic detector cars, which during the past 30 years have located more than 500,000 transverse fissures. The savings: a half billion dollars.

Among early developments, the diesel-electric locomotive was the most revolutionary in the history of railroading. Sutcliffe points out that it was also the most timely, eliminating many transportation bottlenecks that would have hampered seriously the movement of men and materials during the war. Faster schedules permitted greater utilization of available equipment. The 5 to 7% efficiency of the steam locomotive could not compete with the 25% efficiency of the diesel; the manpower required for maintenance was slashed, freeing men for other essential war work; and the increased traction on the rail allowed faster acceleration while pulling longer trains.

Improvements on the diesel-electric locomotive continue, and further research is effected to result in even greater savings in time, expense, and manpower.

Effective research . . . improved efficiency . . . great potential

—and still the railroads are a dying industry.

Electrical stress-measuring equipment, another WW II development, also illustrates present benefits from early research. Strain gages enabled engineers to design more durable crossings. They cost 10% more than the old, but increased the crossing life 50%, so that they now last nine years instead of six.

In addition, stress-measuring equipment opened new vistas in bridge design, resulting in greater dependability. There are 1,800 miles of steel bridges, 1,800 miles of timber bridges and 900 miles of concrete bridges on the railroads of the United States. Present bridge specifications call for the structure to withstand longitudinal braking forces to equal 20% of the vertical load. Recently, strain gages revealed that most of the longitudinal force travels down the rail to the embankments, and very little is transmitted to the structure itself.

Another recently-opened vista is reinforcement of bridges to withstand the increasing weight and size of locomotives. Laminated timber stringers up to 70 feet long, six feet deep, and one foot wide have been tested in railway bridges. Their success could result in substantial savings in bridge construction costs.

Cooling the 'hotbox'

One of the most costly trouble-spots, now research relieved, has been "hotboxes." These overheated journal bearings, resulting from lack of adequate lubrication and many other causes, have plagued the railroads for nearly a century. In 1958 there was one hotbox for every 200,000 car miles in freight service. This means an imaginary car could have traveled around the earth eight times before developing a hotbox.

But when an occasional hotbox does develop, it means expensive repair costs, train and freight delays, possible axle failures, or car derailments. Even occasional hotboxes on the nation's two million freight cars cost millions of dollars annually.

Cotton waste, which has wicking ability to carry the car oil from its reservoir in the bottom of the box to the journal, has been used to pack journal boxes for 100 years. But loose threads may get trapped between the journal and the bearing and wipe off the film of oil that should lubricate the bearing, resulting in a hotbox. R&D has suggested changes in this material and also in the design of the journal bearings.

For instance journal stops—which are brass bars mounted inside the journal box to prevent excessive movement of the journal—have been used with considerable success. More recently, a variety of journal lubricators have been developed in which pads of wool felt, cotton chenille loops, combined with sponge rubber or metal springs, and other integral material have been used to wick the oil to the journal.

Electronics also has been put to work on this problem. An infrared hotbox detector with a magic eye sensitive to heat now has been developed by Servo Corporation of America. This device spots hotboxes on 60 mph trains and serves 21 major roads with 100% accuracy.

Similar unique solutions seem to be the rule for the railroad industry: "piggyback" flatcars, hopper cars, and reinforced flatcars, for example.

Hauling loaded truck trailers piggyback on flatcars teams the perpetual competitors, railroad and truck, for the efficiency of long hauls and the convenience of local delivery. Trucking firms are able to expand operations at a lower capital investment because fewer tractors are required to pull trailers. As the highways become more crowded and the pattern of rates and scheduled deliveries is arranged, the scope of piggyback service will expand rapidly.

Covered hopper cars have been used to haul cement for many years. More recently they have been adapted for shipping flour, starch, and other foodstuffs in special aluminum-lined cars.

Heavily reinforced flatcars, with the section between the trucks depressed to within a few inches of the rail were designed to move oversized equipment. The added clearance permitted transportation of large industrial equipment, much of which previously had to be fabricated at the installation site.

Another unique development is air-inflated pillows for missile parts. Due to extremely close tolerances and delicate mechanisms used in manufacturing supersonic missiles, air freight formerly was considered the only safe means for their transportation, despite the great expense.

Cushioned over inflated pillows, the missile literally floats on air, and can travel as safely on rail as by airplane. Adapting this handling method to all types of sensitive instruments and machinery opens a new field to rail transportation.

Not all research accomplishments are so profoundly simple. The C&O is experimenting with a French-developed welded rail process that could result in big savings on track maintenance and provide a smoother ride. Called "alumino-thermique rail welding," the process can be applied to old rails in place.

Continuous welded rails already in use in the U.S. required welding long sections in shops, moving them to the site on flatcars, and installing them in track with special equipment.

Economy fuel vs. electrification

A no less important research contribution is toward a solution to the problem of rising diesel fuel prices. Properly used, lower-quality fuels (30 to 40 cetane rather than 40 to 50 cetane) give equally good performance at lower cost.

An extensive research program has been initiated by the Southern Pacific Railroad to develop a dual fuel system in order to make satisfactory use of "economy" fuels. Since fuel represents more than half the cost of diesel operation, considerable savings resulted.

Success with economy fuels incited efforts toward utilizing residual fuel, which is even heavier and less costly. It was found that the residual fuel could be used only in particularly strenuous pulls, but current research indicates the cheaper fuel soon may be usable.

In France, the high cost of imported diesel fuel has led to the electrification of most trackage. The French pattern easily could be followed in the United States as the price of diesel fuel continues to rise.

Nuclear railroads?

Fuel and electricity are not lone contenders for powering locomotives. The Navy's success in utilizing nuclear energy to replace diesel power in submarines introduced the possibility of nuclear power for locomotives.

The 10-ft.-wide by 15-ft.-high space limitations of a locomotive, set by existing clearances, present a chal-

lenging design problem. The shielding problems in a locomotive are radically different from those of a submarine. Locomotives would have to rely on air cooling, while a submarine has unlimited quantities of water for cooling. The job of designing an atomic locomotive is even more demanding than the extremely difficult job of designing an atomic submarine.

While initial studies on nuclear-powered locomotives have been made (at Armour Research Foundation and elsewhere), they have not been researched more vigorously simply because there are many other more practical, pressing, problems. Research, like any other phase of management activity, requires good judgment. To have undertaken large-scale research to save horse-drawn transportation would have been futile, for all the research that could have been commanded at the time would not have maintained the competitive position of the horse against its gasoline-powered competitors. There is never an absolute guarantee that research will achieve a given goal.

The many millions of dollars which the railroads have saved through research are not necessarily reflected as increased profits because of boosted wages and taxes and other operating costs. As often as not, the findings of research are used as a means of remaining competitive; they show on the profit-and-loss ledger only as having prevented a reduction in the profit rate, or even remaining in business.

Clearly, research is not enough. Albert Beatty, assistant vice-president for the Association of American Railroads, says the railroads cannot survive without: the same regulation and taxation as given other kinds of transportation; equal terms to meet competition; and termination of direct and indirect subsidy of railroad competition.

If these goals are not achieved, there are two alternatives: bankrupt railroads or federal ownership. Whether the latter results from the former, or comes about more directly, the solution is inevitable and unfortunate.

Aside from the social implications of nationalization, U.S. federal ownership has proven itself inefficient; a case in point is the $2 million loss *per day* encountered when the government ran an even smaller railway system during World War I. The ceaseless political tug-of-war in England is a more current unhappy example. Continuing under present inefficiencies is not the answer. Neither is nationalization. And neither is research alone ■

SILICONE NEWS from Dow Corning

Cast Fine Detail Quickly

STRIP IT

MOLTEN METAL

Parting is easy... Silastic RTV seldom requires the use of a release agent: The mold strips easily from most surfaces. In cases where a release agent *is* needed, a simple solution of household detergent does the job.

Symphony in RTV. Just to illustrate how accurately Silastic RTV reproduces detail, Dow Corning has made Silastic RTV molds of 33⅓ and 45 rpm records, then cast plastic records from them. Result: excellent sound fidelity!

IDENTICAL TWINS

Choose your cure. Some types of Silastic RTV set up to solid rubber five minutes after the catalyst is mixed in. Others cure in 24 hours . . . stay "open" and workable a long time. Write for details!

SILASTIC RTV
SILICONE RUBBER

flows in and around complex shapes; sets up in minutes

The incredibly life-like hand above was cast of rubber. It was made from a mold of the same material: Silastic RTV, the Dow Corning fluid silicone rubber that vulcanizes at room temperature.

The striking detail reproduced here — detail that would stir the heart of a Madame Tussaud — can be duplicated by you in your own plant. With ease. Simply pour liquid Silastic RTV into or around any object you wish reproduced. Wait a short time while the fluid sets up to form rubber. No heat-vulcanizing is needed. Now strip the rubber away and you have a mold for making exact reproductions. Into this you can pour a variety of casting materials including many plastics, molten metals . . . even more Silastic RTV.

POUR IT

The Perfect Prototype... Silastic RTV is the answer to a prototype-part maker's prayer. Because of its heat resistance — temperatures to 500 F are easily withstood — many molten substances can be cast directly in Silastic RTV. If you want to make a limited run of some part for use as test models, samples or give-aways, you can do it with only one mold.

Free Sample. Write on your letterhead of data and sample of Silastic RTV. Address Dept. 4722.

first in silicones

Dow Corning CORPORATION
MIDLAND, MICHIGAN

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS LOS ANGELES NEW YORK WASHINGTON, D. C.

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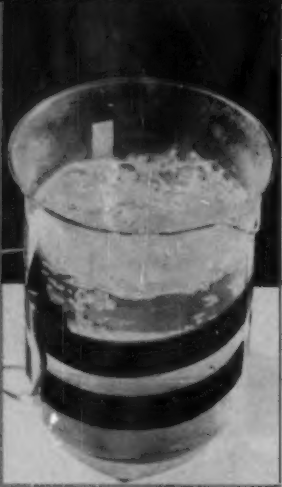


RESEARCH

TRENDLETTER

4th quarter, 1959

Dear Sir:

"The next 10 years probably will be known as the decade of materials research," predicts Midwest Research Institute president Dr. Charles Kimball. Environmental conditions in space and on earth are the main incentives.

The impact of materials research on industry can be seen in wider use of plastics, ability of materials to withstand high temperatures, new chemical applications, electronic systems, coatings, and lighter metals.

One important breakthrough in materials research is a new graphite fabric that possesses all the qualities of manufactured graphite. Produced by thermochemically converting the crystalline structure of organic textile into that of graphite, it shows promise as a more versatile substitute for graphite products.

The fabric has no melting point under ordinary pressures, conducts heat (photo 1) and electricity (photo 2), reflects heat (photo 3), and resists acids, alkalies, and organic compounds. It becomes stronger at high temperatures and remains unaffected as low as -320F.

The lightweight (about .04 lbs per sq in.) cloth could be used to reinforce plastics and refractory materials, such as missile nose cones, to impart electrical and thermal conductivity to non-conducting materials, and to provide heated clothing for space travelers, according to National Carbon Co, 100 E 42 St, NY 17.

Applications in chemistry: bag-type filters for non-oxidizing gasses, equipment to handle corrosive fluids, electrostatic precipitators, curtain walls, and flame arrestors.

Electrical uses include resistance-heating elements, thermoelectric elements, vacuum-tube grids, infrared emitters, and static eliminators. Plating, spraying, or vacuum depositing of metals on graphite textiles facilitates making electrical connections.

Other applications include valve packing and gasket materials for high-temperature seals

such as those in jet engines, low-temperature panel heating, and conveyor belting for high-temperature equipment. The nuclear properties of graphite enable the fabric to slow down high-velocity neutrons to thermal speed without appreciable neutron absorption.

◄ A remarkable new material made from powdered aluminum oxide has the composition of a ceramic, structure of a metal, and light-transmitting properties of glass. Called "Lucalox," it's a polycrystalline made by General Electric Co, Schenectady, NY. A bar of Lucalox can support 50 grams up to 3200F, while quartz bar bends.

Lucalox is strong, but can be pressed into any shape. Possible applications are in high-intensity incandescent and discharge lamps used to test missile nose cones, and many other devices requiring transparent envelopes.

electronics

An important advance in semiconductors, the tunnel diode has been discovered by Leo Esaki, a Japanese scientist. It is a practical application of "quantum-mechanical tunneling." The term is used to describe the manner in which electrical charges move through the device—with the speed of light, in contrast to the relatively slow motion of electrical charge carriers in transistors.

◄ The tunnel diode will be a boon to computers, communications, nuclear control, satellites, and space vehicles because of its speed, modest power needs, insensitivity to temperature change, ruggedness, low noise level, simplicity, and small size.

◄ A p-n-p-n semiconductor element that can serve as the basic building block of a silicon stepping switch has been developed at Bell Telephone Labs, 463 West St, NY 14. Photo magnifies the device 100 times. Potential applications: digital computers, pushbutton dialing, and telephone switching.

metallurgy

A fresh outburst of attention will be paid to titanium in the next few months. Widely researched, the steel-strong lightweight metal has been so difficult to obtain that past production has been low.

Now the Norton Co, Worcester 6, Mass. hopes to reduce the difficulty and expense of obtaining titanium with its new electrolytic process. Norton will produce 99.6% pure titanium from titanium carbide—an inexpensive compound containing three times as much titanium as currently-used titanium tetrachloride.

Also, Du Pont will establish a new research center at its titanium-dioxide plant in Baltimore to study titanium and refractory metals.

chemistry

High-purity petrochemical products are assured by recent advances in gas chromatography that permit production of materials so pure they require new standards of measurement. Contamination of less than 1/100% can be detected in waxes, oils, foods, and drugs, says Gulf Oil Research Labs, Pittsburgh.

Rugged new polymers which do not have the traditional carbon-to-carbon chains have been developed by R. N. Haszeldine of Manchester Univ, England. He is studying monomers which contain bonds between two elements where either one or both are atoms of elements other than carbon. Elements getting most attention are phosphorous, boron, silicon, and nitrogen.

Solid-fuel chemists are turning to aluminum in their search for greater energy. Increases of 10% to 30% in solid-fuel thrusts are now possible with aluminum powder as an additive, according to Atlantic Research Corp, Arlington, Va.

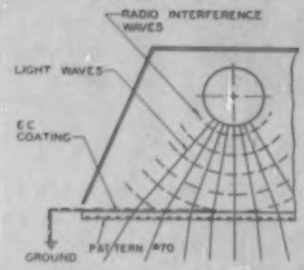
computers

R&D continues to boost computer speeds and versatility. Small size and high shock strength are stressed.

An unusual matrix calculus computer has been designed by Washington Univ, St. Louis, Mo, to operate with differential, algebraic, and integral matrix equations. Said to possess complete stability in operation, it can be used directly by the researcher for linear transformations and matrix produces.

◀ Another computer—an advanced high-speed digital plotter for complete flight evaluations—is said to be 17 times faster and 12 times cheaper than previous models. Developed by Lockheed Missiles & Space Div, Sunnyvale, Calif, the plotter's transistorized circuitry and high-speed magnetic tape make a graph in one operation.

"Videograph," combining techniques of electrostatic printing and TV, transmits and reproduces documents and photographs moving objects on paper or a TV screen. A.B. Dick Co, 310 N Dearborn St, Chicago says an electrostatic printing tube boosts speed to 10,000 lines a min. (Previous top speed—1,500 lines a min.)



now available:

◀ Glass lighting panel. . . Radio interference caused by fluorescent lighting is eliminated with a new coated optical panel that fits over the lighting fixture. Coating is a thin, transparent electrically-conductive film which intercepts the radiated interference, grounded by a 1/4-in. wide silver strip fired into the film around the glass. Available from Corning Glass Co, Corning, NY.

◀ Shock absorbing material. . . A raw egg would bounce off Ensolite after a 10-story fall, says U.S. Rubber Co, NY 20. Fire-resistant Ensolite will be useful as a padding material in water safety, athletic, and other equipment.

◀ Alumina tubes. . . Porous alumina tubes for melting and high-heat treatment (up to 3450F) has been developed by Morganite Inc, 3300 48 Av, L.I. 1, NY, for use in hydrogen and cracked ammonia reducing atmospheres.

◀ Magnetic shielding kit. . . The Perfection Mica Co, 1322 N Elston Av, Chicago 22 offers kits permitting the design engineer to evaluate how many layers of material are needed, what configuration, etc. Cost from $24.90 to $99.50.

Selectively fluorinated products. . . Du Pont is manufacturing a unique chemical—sulfur tetrafluoride—which opens a new range of selective fluorination in pharmaceuticals, oils, and plastics. The chemical reacts effectively with ketones, carbonyl compounds, and carboxylic acids.

◀ Electronic fish-finder. . . A portable instrument bounces ultrasonic signals off the bottom of a body of water to indicate depth of water, type of bottom, and "where the fish are." Raytheon Corp, Waltham, Mass. says the fish-finder will sell for $125.

◀ Inexpensive radioactive fallout detector. FIDO fallout intensity detector oscillator is being marketed by Controls for Radiation Inc, Cambridge, Mass. Accurate and small, it sells for $10 to $15.

Sincerely,

F B Fragale

Assistant Editor
INDUSTRIAL RESEARCH

We Have Taken the "Rare" out of "Rare Earths"

You Now Have a Wide Choice of Readily Available Materials

a report by LINDSAY

We were thinking the other day of the progress we have made in taking the "rare" out of "rare earths." Even the "earth" in rare earth is not completely descriptive, either.

Actually, the name rare earths does fit these elements into the periodic system, for they are earthy when in the form of oxides. In this respect, they resemble the "earth" elements, aluminum being a good example. The "rare" came from the fact that those wonderful chemists of the last century thought that they were indeed rare, since the only supplies available were derived from quite rare and exotic minerals found then in a very few pegmatitic deposits in Norway.

Now, of course, you can buy rare earths in almost any size, shape and form. You can order in grams, ounces, pounds, and in many cases in carloads!

These elements have been described by other names such as "lanthanides" and "lanthanons." Technically, these are the elements lanthanum, atomic number 57, and the next fourteen elements in the periodic system. Thus, rare earths include all the elements from atomic number 57 to 71 (lanthanum to lutetium).

Due to some remarkable similarities in properties, the rare earths tend to occur together in nature. These same properties make it difficult to separate them in some cases. From the standpoint of availability of commercial materials, there are several choices.

THE RARE EARTHS

ATOMIC NUMBER	ELEMENT
39	Yttrium
57	Lanthanum
58	Cerium
59	Praseodymium
60	Neodymium
62	Samarium
63	Europium
64	Gadolinium
65	Terbium
66	Dysprosium
67	Holmium
68	Erbium
69	Thulium
70	Ytterbium
71	Lutetium
90	Thorium

Rare Earth Materials. The ore mineral commonly used as a source of rare earths is monazite. Rare earths extracted without any appreciable separation are marketed commercially as "rare earth" salts or materials. They contain these elements in about the same ratios as in the ore: roughly one-half cerium, one-quarter lanthanum, one-fifth neodymium, about five per cent praseodymium, and smaller amounts of the other rare earths. Being close to the starting material, "rare earth" salts are the most economical.

Cerium. Cerium is the most important single rare earth, relatively easy to separate and available in a rather complete range from commercial to high purity grades.

Didymium. Taking cerium out of the rare earth mixture leaves a collection of rare earths we call "didymium." Didymium materials, like cerium, are close to the starting ore, so costs aren't excessive.

High Purity Materials. *Lindsay* pioneered the first commercially installed ion exchange plant for the production of individually separated rare earths in purities up to 99.99%. These high purity materials are now readily available at prices which were unheard of only a few years ago.

Many applications. We have made remarkable progress . . . through the development of improved techniques for the separation of the rare earths, and expansion of production facilities . . . in taking the "rare" out of "rare earths." Needless to say we were compelled by considerable urgency to satisfy the rapid growth in demand by industry for many new uses.

• • •

We have prepared a revised edition of our technical data describing our rare earth, yttrium and thorium materials. Your request for the "Lindsay Binder" will bring you this collection of data promptly. If you have a specific idea or use in mind, let us know and our technical people will try to supply pertinent data.

We show you this photo of bulk handling of rare earth intermediates at our West Chicago plant to suggest that rare earth materials are produced in large tonnages. They are available for prompt shipment, some of them in carload quantities. Prices, incidentally, are surprisingly low.

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NEW MATERIALS

1. steel-hard glass

2. grainless film

What's happening to pyroceram?

ANNOUNCED IN 1957, "Pyroceram"—the glass that can be made harder than high-carbon steel, lighter than aluminum, and resistant to deformation at high temperatures—has all but vanished from the press.

In the past two years, extensive product development has been going on at Corning Glass Works, Corning, N.Y. The program has led to production of such widely divergent products as missile radomes and cooking-serving ware for the home.

Ultimate goal, according to pyroceram inventor Dr. S. D. Stookey, is development of materials that are even more superior in resisting heat, mechanical breakage, or chemical attack. Among the many new applications of the materials now under study, for instance, are pyroceram products for chemical processing equipment.

In mechanical properties, pyroceram glass-ceramics are now generally higher in Young's modulus than glasses, ranging from 12.5 million to 20 million psi with strengths higher than glasses and most ceramics.

Some of the materials are resistant to high temperatures in terms of both strength and oxidation. Some are lighter and harder than most metals. In thermal conductivity, some are classed as heat insulators. Some are like glasses in their ability to resist chemical attack with measured durabilities in weight-loss comparable to the durable chemical glasses.

Several thousand types of pyroceram have been made experimentally. Dr. Stookey — who holds 28 patents in glass and related developments — expects that the family of glass-ceramics eventually will offer as many compositions as glass itself.

In one successful production run of a general-purpose glass-ceramic (9608), every kind of article from ball bearings to beakers was produced. Items included tubing, skillets, sheet glass, and even large telescope mirror blanks. It represented a million dollar "vote of confidence" in a glass that had to be formed hotter than any large-scale production glass ever made.

The run clearly demonstrated the commercial possibilities of pyroceram. Within a matter of months, a line of cooking-serving ware was on the market. Radomes are being produced today in the hundreds. A host of other products have been produced for sampling, evaluation, and testing.

Considerable advances have been made, for example, in production of high-temperature, corrosion-resistant bearings of pyroceram. Successful tests have been carried on without lubrication at temperatures of 1000 F, under both

1

1. CERCOR BLOCK *is heated bright red on one side, yet remains cool on opposite side.*

2, 3, 4. COLD-WATER PLUNGE *hardly affects this red-hot Pyroceram rod, demonstrating its high resistance to thermal shock.*

5. PYROCERAM INVENTOR, *Dr. Donald Stookey.*

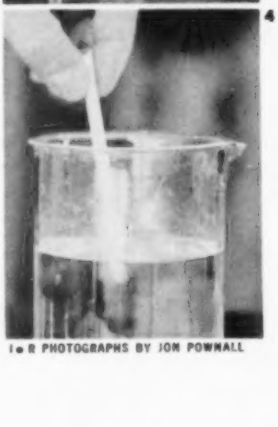
6. LOW-VISCOSITY *Pyroceram can be melted and poured like metal for wide applications.*

2

5

3

6



4

I • R PHOTOGRAPHS BY JON POWNALL

heavy and light loads.

Sliding tests in corrosive media have shown lower co-efficients of friction and less surface wear or damage occurred when sliding pyroceram against itself or against metal than when sliding metal against metal. Rolling tests conducted without lubrication between pyroceram and high temperature metal balls (at 1800 F) showed little wear or surface damage on pyroceram or balls.

Pyroceram is one of the base materials for a new group of thin-walled cellular ceramic materials called "Cercor." Corrosion resistant, these materials are able to operate at high temperatures (1000 C for short terms, 700 C continuously) with excellent thermal shock resistance because of their virtual zero thermal expansion.

With high surface area and low expansion, cercor corrugated ceramics are beginning to be used in gaseous heat exchangers as catalyst supports, and in structural, acoustical, filtering, flow control, and insulating applications.

From the outset, pyroceram attracted the interest of the aircraft and missile industry, for certain missile radomes and for flush-mounted radomes, the "antenna windows."

Why pyroceram? Properties can be held constant during fabrication. Glass-ceramic radomes can be manufactured with greater speed and ease than radomes of other materials such as alumina or fiber glass laminates.

Pyroceram radomes can be produced with extremely good di-electric properties over a broad temperature range. Glass-ceramic radomes will withstand 2200 F for short terms without deforming.

In electronics, pyroceram cement is being used to seal glasses, ceramics, and metal in the high-melt range — for instance, to seal the face panel to the funnel of all-glass color television bulbs, or to embed hundreds of lead wires in the four-inch faceplate of a multiple target cathode ray tube.

These are just a few of hundreds of present and potential applications inherent in pyroceram's basic advantage over other materials. Service temperatures of plastics, for instance, have gone up but are limited to a few hundred degrees centigrade.

Metal alloys have been developed for high temperature use, but are subject to oxidation and degradation of properties at elevated temperatures. And since they are not electrical insulators, they are ruled out for many applications.

Ceramics, too, have been produced for high-temperature products, but many of these materials are porous and have large crystal grain size which

PYROCERAM NOSE CONE *is inspected in glassy state by Corning's H. B. Younker. Heat treatment will transform cone to an opaque ceramic.*

reduces their mechanical strength. Many are difficult to fabricate to accurate dimensions and large shapes.

High-temperature glasses, such as fused silica, have been made. But they are relatively expensive, difficult to fabricate, and do not have the broad range of physical properties available in pyroceram.

Development of pyroceram has been highly successful — and expensive. Corning regularly allots twice the percentage of sales dollars for research as does the average American industry. The firm's research laboratories, formally organized 51 years ago, today have more than 340 scientists engaged in fundamental and applied research.

Boiled film

An interesting photographic material that is developed in boiling water is being marketed to industrial, amateur, and research photographers by Charles Beseler Co., East Orange, N.J.

Called "Slide-O-Film," the material is sensitive only to ultraviolet light. But there being sufficient uv in any concentrated-filament projector bulb, the film, in effect, is sensitive to practically all light sources. Thus it is used for making black-and-white negatives of either b&w or color transparencies. It is not suitable for direct photography, however, because of its very slow speed.

For halftone or line copy work, for making positive projection slides from b&w or color negatives, Polaroid transparencies, or for blowing up movie film frames, the material is ideal. After a 20 to 60-second exposure, the film is developed merely by dipping

BOILING WATER
or other heat source develops a halftone or line reproduction made on Beseler's Slide-O-Film.

into boiling water or subjecting it to any other heat source between 212 and 250 degrees F.

Slide-O-Film appears to be ideal for photo-offset printers. For instance, a printer may wish to send several proofs from original offset negatives to his client — which he can do without darkroom or chemicals.

Similarly, slide-o-film can be used to make quick positives from x-ray negatives. In this way, radiologists can make many duplicates and send them to several experts for analysis.

In polaroid photography, slide-o-film serves a unique purpose. It is now just as easy and as fast to get a negative from a polaroid slide as it was to get the "picture in a minute" slide in the first place.

Since this material contains no silver nitrate in any form, it is totally free of grain (except for the almost non-existant grain of the base itself). As a result, copies can be made with higher resolution than available in even the finest fine-grain film. Images, therefore, can be projected to any size without loss of detail — as long as sufficient contrast remains to make the image discernible.

The base of slide-o-film is du Pont's Mylar, which resists tearing. The image is non-fading. Actually the older a slide-o-film, the more permanent it becomes.

Slide-o-film, developed for Charles Beseler Co. by the Kalver Corp., New Orleans, is similar to the older "Kalfax" film produced by Kalvar. Kalfax, however, does not have the wide range of sensitivity peculiar to slide-o-film, the characteristic that makes it satisfactory for halftone work. ■

There are too many magazines already. Time is my most precious commodity. Why waste it reading about other people's ideas? Only with money can I buy time. Why spend money for your magazine when I can use it to pay someone to get ideas. Besides, ideas are dime a dozen. Who needs them? All I lack is time . . . time . . . time . . . I am a busy executive. I administer engineering projects. I don't need ideas and I don't read Industrial Research. This way, I save $5 every year, or $9 every two years, or $13 every three years. My name is Vacuum.

Time is my most precious commodity. I can turn it into money, accomplishment, love, or happiness. All I need is an idea and a thousand sub-ideas. Anything that supplies me with workable ideas is worth money. I pay engineers tens of thousands of dollars a year to work out ideas. If Industrial Research gives me one workable idea it's well-worth the $5. If it gives me 100 ideas, I'll replace my engineers with it. My name is Progress.

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(Heavy numerals refer to issue numbers in volume one.)

Ceramic fiber takes many forms—extends heat limits of fibrous insulations

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